# Final report of Working Group 1:
# **In-depth accident observations and injury statistics**

A COST Action TU1101 / HOPE collaboration

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- www.bicycle-helmets.eu
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The European COST Action TU 1101 is an expert network focusing on improving bicycle traffic safety with a special focus on helmets [1]. As partners of this network the Universities Hannover (Germany), Pavia (Italy), Heraklion and Athens (Greece), Lisbon (Portugal) as well as the Finnish Motor Insurers Centre Helsinki and AGU Zürich (Switzerland) worked together in one working group (WG 1) dealing with 4 different topics:

# A. Report on injury situation of bicyclists in traffic accidents on a European level with focus on helmet usage
# B. In-depth accident analysis of head injuries and the effectiveness of the bicycle helmet in real accident situations
# C. Habits of helmet usage of cyclists by means of a reporting problems in comfort, temperature and climatization reported by questionnaire requests
# D Identifying the influences of the seating geometry, the posture and the helmet position of cyclists on safety aspects

# A. REPORT ON INJURY SITUATION OF BICYCLISTS IN TRAFFIC ACCIDENTS ON A EUROPEAN LEVEL WITH FOCUS ON HELMET USE

It was very difficult to find data of the real numbers of injured bicyclists for all European countries.The numbers given in existing sources are often different and seem to be sometimes incorrect. There are official bodies and European associations presenting data, many times not covering all European countries. For Europe data on traffic accidents are published by IRTAD , CARE or ERSO based on the DACOTA Factsheets.

Taken from the DaCoTA Basic Fact Sheet 2012 which is mainly based on CARE-Data of the years 2010 and earlier, cyclists currently represent around 5% of all fatalities in IRTAD countries, with an increasing trend since 2010 [2]. In Europe bicycle fatalities make up to 6.8% of the total number of road accident fatalities in 2010 in the EU-20a countries. In these countries, 1,994 people riding bicycles were killed in traffic accidents in 2010, which is 9% less than the 2,196 bicycle fatalities reported in 2009. Here, there was a decrease of 38% during the decade 2001-2010 in the number of bicycle fatalities.

[1] IRTAD International Traffic Safety Data and Analysis Group, http://www.internationaltransportforum.org/Irtadpublic/index.html

[2] Citizens Consular Assistance Regulation in Europe, http://ec.europa.eu/transport/road_safety/specialist/statistics/index_en.htm

[3] European Road Safety Observatory http://www.erso-project.eu/

[4] http://www.dacota-project.eu/

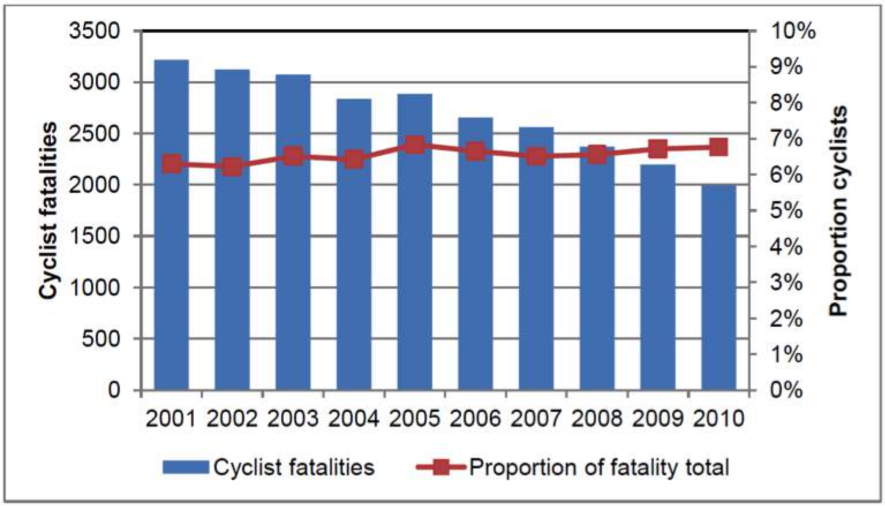



**Figure 1: Number and proportion of cyclist fatalities in the EU-20a countries between 2001 and 2010.**

Figure 1 shows both the number of cyclist fatalities and the proportion of the fatality total in the EU-20a countries between 2001 and 2010 [3]. In this period the decrease of bicycle fatalities was 38%. The Eu 20a countries according to the basic fact sheet include the following countries: Belgium, Czech Republic, Denmark, Ireland, Spain, France, Germany, Greece, Luxembourg, Hungary, Italy, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Finland, Sweden and the United Kingdom.

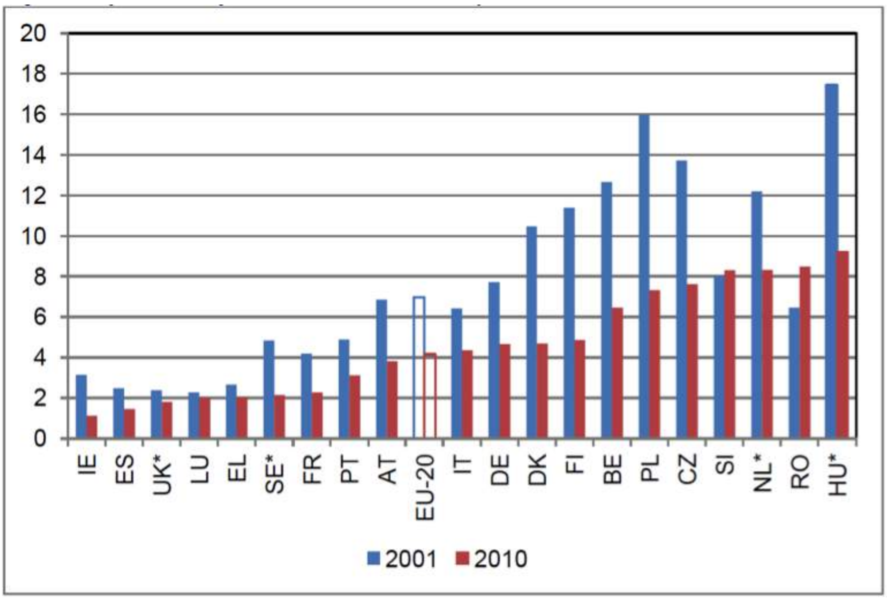



**Figure 2: Cyclist fatality rates, 2001 and 2010 compared, EU-20a**

In Figure 2 the fatality rate is displayed for the EU-20a countries for 2001 and 2010. This is defined as the number of bicycle fatalities per million inhabitants. While these rates fluctuate somewhat from year to year, there has been a general notable decrease in rates for the EU-20a countries over a ten-year period. Fatality rates in Romania and Slovenia presented an exception in which an increase in the ten-year comparison was evident.

It can be seen from Table 1 that the EU countries with the highest percentage of bicycle fatalities in 2010 were The Netherlands (21%) and Hungary and Slovenia (both 12%). In contrast, in Greece (EL) and Ireland cyclists constitute only a small part (2%) of the road accident fatalities.

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| BE | 9% | 8% | 9% | 7% | 7% | 9% | 8% | 9% | 9% | 8% |
| CZ | 11% | 11% | 11% | 9% | 9% | 10% | 10% | 9% | 9% | 10% |
| DK | 13% | 11% | 11% | 14% | 12% | 10% | 13% | 13% | 8% | 10% |
| DE | 9% | 9% | 9% | 8% | 11% | 10% | 9% | 10% | 11% | 10% |
| IE | 3% | 5% | 3% | 3% | 3% | 2% | 4% | 5% | 3% | 2% |
| EL | 2% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 2% |
| ES | 2% | 2% | 1% | 2% | 2% | 2% | 2% | 2% | 2% | 3% |
| FR | 3% | 3% | 3% | 3% | 3% | 4% | 3% | 3% | 4% | 4% |
| IT | 5% | 5% | 5% | 5% | 6% | 5% | 7% | 6% | 7% | 6% |
| LU | 1% | 2% | 0% | 0% | 2% | 0% | 2% | 0% | 4% | 3% |
| HU | - | - | 13% | 14% | 12% | 12% | 13% | 11% | 13% | 12% |
| NL | 20% | 17% | 18% | 20% | 20% | 25% | 21% | 21% | 21% | - |
| AT | 6% | 8% | 6% | 7% | 6% | 7% | 5% | 9% | 6% | 6% |
| PL | 11% | 12% | 11% | 12% | 11% | 10% | 9% | 8% | 8% | 7% |
| PT | 3% | 3% | 4% | 4% | 4% | 4% | 4% | 5% | 3% | 4% |
| RO | 6% | 5% | 7% | 5% | 8% | 8% | 6% | 6% | 6% | 8% |
| SI | 6% | 7% | 0% | 8% | 7% | 6% | 6% | 8% | 11% | 12% |
| FI | 14% | 13% | 10% | 7% | 11% | 9% | 6% | 5% | 7% | 10% |
| SE | 7% | 8% | 7% | 6% | 9% | 6% | 7% | 8% | 6% | - |
| UK | 4% | 4% | 3% | 4% | 5% | 4% | 5% | 4% | 4% | 6% |
| *EU-20a* | *6,3%* | *6,2%* | *6,5%* | *6,4%* | *6,8%* | *6,6%* | *6,5%* | *6,6%* | *6,7%* | *6,8%* |
| BG | - | - | - | - | - | - | - | - | - | - |
| EE | - | - | - | - | 4% | 6% | 7% | 7% | 7% | - |
| CY | - | - | - | 2% | - | - | - | - | - | - |
| LV | - | - | - | 7% | 8% | 8% | 6% | 6% | 12% | 7% |
| LT | - | - | - | - | - | - | - | - | - | - |
| MT | - | - | - | - | - | - | - | - | - | - |
| SK | - | - | - | - | 9% | 8% | 9% | 8% | 6% | 7% |

**Table 1: Percentages of cyclist fatalities in the total number of road accident fatalities, 2001-2010 Source: CARE Data**

Figure 3 indicates that over a ten-year period (2001-2010), there has been a marked reduction in cycling fatality numbers across almost all ages in the EU-19 countries (EU-20a except for Hungary). This figure displays also a clear trend in fatalities evident both in 2001 and 2010: there appears to be a peak in fatalities of cyclists aged between 12 and 17, the age where children are likely to increasingly be undertaking independent, solo cycle travel. A general decrease in fatality risk then follows till around 30 years, at which point a continuous if jagged increase in fatality numbers is evident till around 80 years. After this, there is a relatively sharp decline.

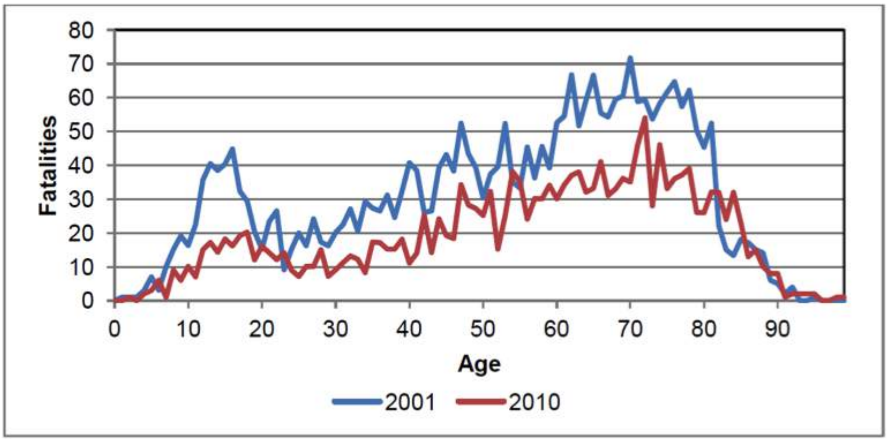



**Figure 3: Ten-year comparison of cyclist fatalities by age in EU-19 countries**

Figure 4 shows that 35% of cyclist fatalities in 2010 in the EU-23 countries occurred in July, August and September. The proportion of cyclist fatalities during January, February and March is only 13%. As the slippery wet conditions of many European winters are conducive to high severity accident injuries, these analysis outcomes are likely to be associated with the actual number of cyclists on the road during these seasons rather than an indication of risk of injury per cyclist.

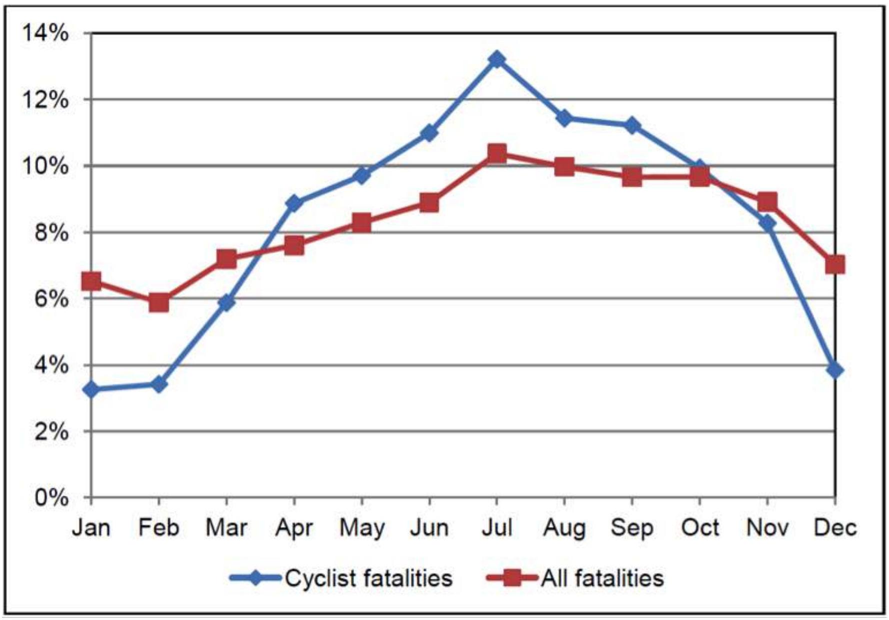



**Figure 4: Proportion of cyclist fatalities and all fatalities per month in 2010, EU-23 (BE, CZ, DK, DE, EE*, IE, EL, ES, FR, IT, LV, LU, HU, NL*, AT, PL, PT, RO, SI, SK, FI, SE*, UK*). * Data from 2009**

In general, 55% of the bicycle fatalities in the EU-23 countries occurred inside urban areas but there are large differences between the countries, as follows from Figure 5. In Romania, almost 70% of cyclist fatalities occurred in urban areas, in Spain only 26%.

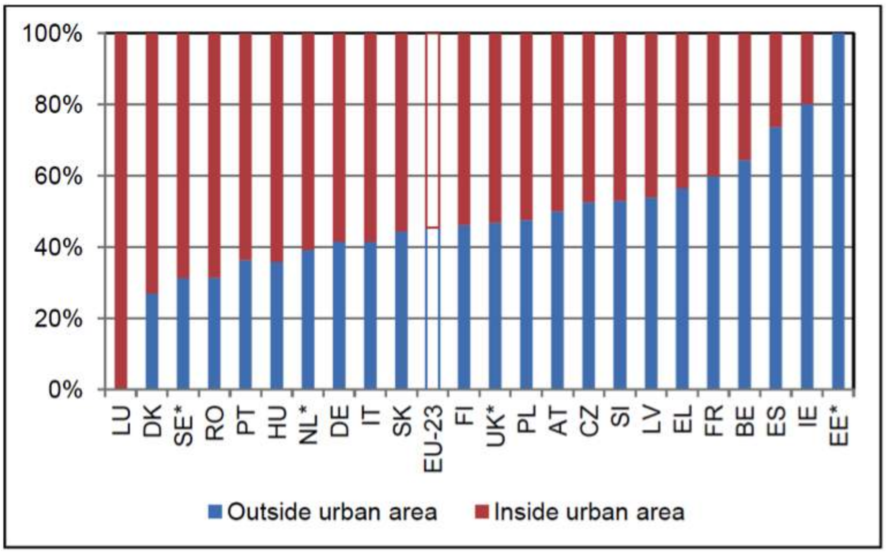



**Figure 5: Distribution of cyclist fatalities by area type in 2010, EU-23 (* Data from 2009).**

Figure 6 shows the distribution of cyclist fatalities by junction. Focusing on cyclist fatalities at junctions, 55% occurred at crossroads and 7% at T-junctions or staggered junctions. In Germany, The Netherlands and Poland more than 85% of cyclist fatalities at junctions occurred at crossroads. In the United Kingdom 52% of the junction cyclist fatalities occurred at T-junctions or staggered junctions.

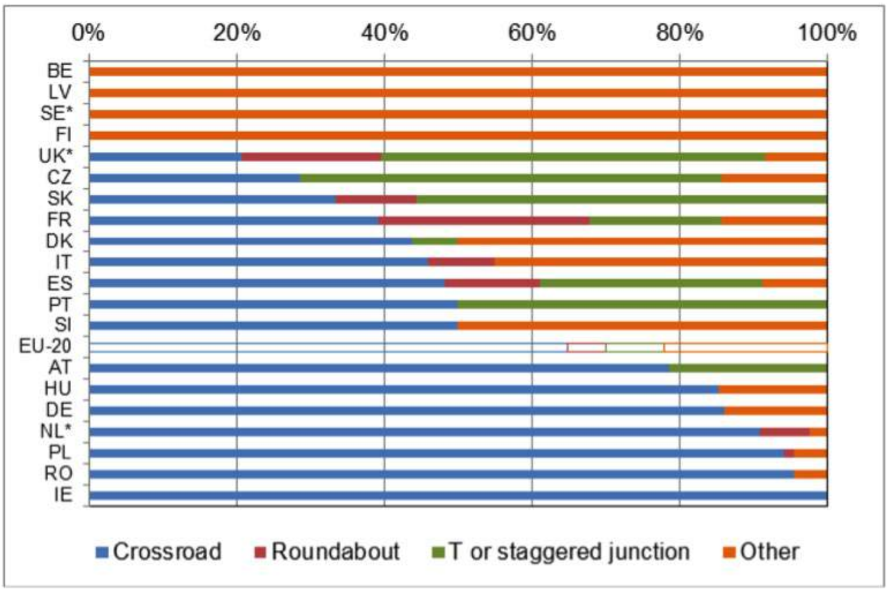



**Figure 6: Distribution of cyclist fatalities by junction type in 2010, EU-20**

The extent to which different types of people and cyclists' characteristics seem relevant to the usage of bike helmets was to be investigated. To this end, the parameters age of rider, type of bicycle, choice of road or bike paths and the location (inside/outside of built-up areas) at the time of the collision were used for comparison purposes.

The surveys at the scenes of accidents (Figure 7) showed helmet wearing rates in cyclists injured in accidents rising from (8.5%) in 2000 to (17.0%) in 2010. In 2011, however, a total of only 10.8% of the cyclists involved in an accident wore a helmet. Corresponding figures for 2012 are not yet available.

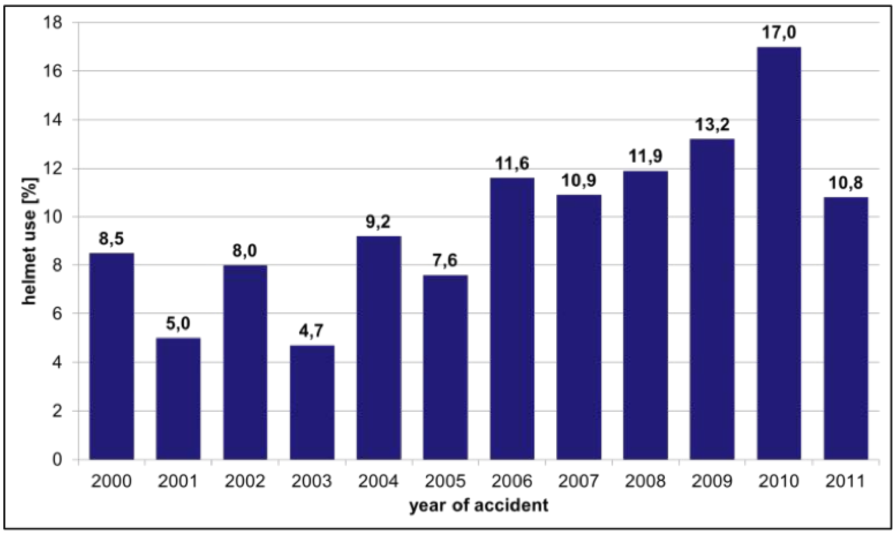



**Figure 7: Helmet wearing rates in traffic accidents in GIDAS [4], the same survey methodology was applied over the whole period depicted.**

9.7% of the bicyclists inside of built-up areas wore a helmet vs. 23.0% outside of built-up areas. The helmet wearing rate outside of built-up areas was more than twice as high as that inside towns, which might be related to the fact that outside of built-up areas rather longer road trips are undertaken than inside towns and the corresponding need for protection on the side of cyclists may be higher. Cyclists more frequently wore helmets in the daytime (10.6%) than at night (8.8% in darkness, 8.7% during dawn or dusk). The type of bicycle has a special correlation to the helmet wearing rate for sporty bicycles. 43.1 % of the racing cyclists, 17.8% of the BMX riders and 11.8% of the mountain bikers wore helmets at the time of the accident, compared to only 8.8% of the riders of touring cycles. It was conspicuous that 13.5% of the cyclists wearing a helmet were riding on the street at the time of the accident, compared to 8.0% of the cyclists who were using a bike path. The choice of the route is obviously connected to the type of bicycle. It can be stated that 49.9% of the racing cyclists and 47.9% of the BMX riders used a bike path, while 59.4% of the touring cyclists were on a bike path at the time of the accident. The age distribution between wearers of bicycle helmets and bicycle riders not wearing a helmet shows substantial differences. In particular it can be noted that older cyclists often did not wear a bicycle helmet. I.e. 45.0% of the cyclists without helmet were of the age 40+, whereas only 32.4% of those with helmet were of the age 40+. The helmet wearing rate was 11.8% in the age group 41-50 years, whereas for older riders aged 51-60 years it was 6.0%, for 61-70 years 6.8%, and for those aged 70+ years it was 3.3%. The highest helmet wearing rate of bicyclists involved in accidents occurred in children up to 10 years of age at 38.1%.

# ROAD ACCIDENT HEALTH INDICATORS

Injury data can be obtained from a wide range of sources, such as police and ambulance reports, national insurance schemes, and hospital records, each of which provides a specific but yet incomplete picture of the injuries suffered in road accidents. In order to obtain a comprehensive view of these injuries, the EU Council issued a Recommendation that urges member states to use synergies between existing data sources and to develop national injury surveillance systems rooted in the health sector. At present, thirteen member states are routinely collecting injury data in a sample of hospitals and delivering these data to the Commission. This system is called the EU Injury Database (EU IDB) and consists of data from a selection of about 100 hospitals across the EU which provide around 300,000 cases a year for uploading in the EU-database.

Within the EU IDB "transport module" injuries suffered in road accidents are recorded by "mode of transport", "role of injured person" and "counterpart". These variables can complement information from police records, in particular for injury patterns and the improved assessment of injury severity. The indicators used include the percentage of casualties attending hospital who are admitted to hospital, the mean length of stay of hospital admissions, the nature and type of body part injured, and potentially also long term consequences of injuries.

Figure 8 is based on IDB data from nine countries (DE, DK, LV, MT, AT, NL,SE, SI, CY) for accidents that occurred between 2005 and 2008. Vulnerable road users (pedestrians, cyclists, motorcyclists and mopeds riders) accounted for almost two thirds (63%) of road accident casualties attending hospital, and for over half of casualties admitted to the hospital (56%).

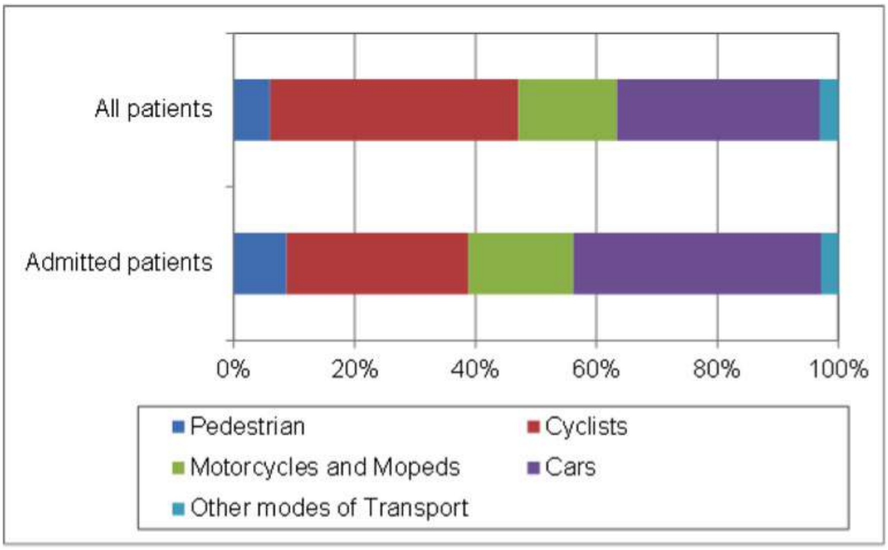



**Figure 8: Distribution of non-fatal road accident casualties attending hospital, by mode of transport**

Figure 9 (same data source as Figure 8) shows that 32% of road accident casualties recorded in the IDB were admitted to the hospital overall, and 23% for cyclists.

[5] http://ec.europa.eu/health/data_collection/databases/idb/index_en.htm

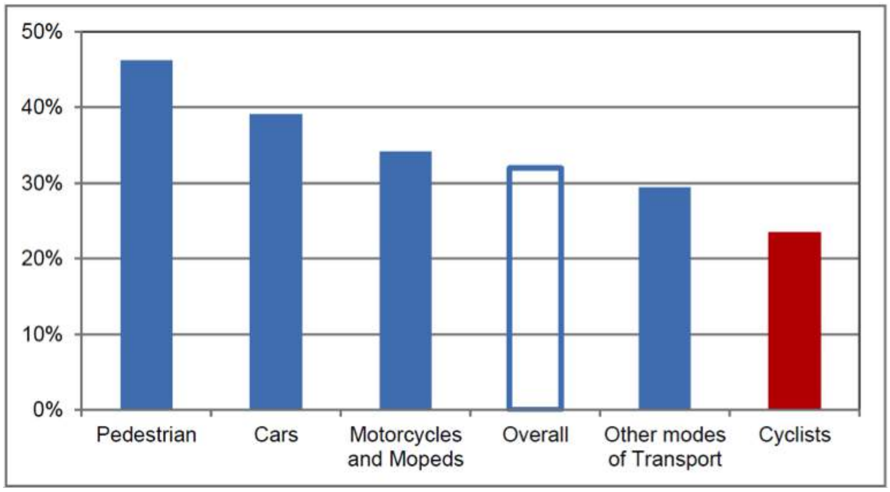



Figure 9: Share of casualties who attended a hospital who were admitted to hospital, by mode of transport

Naturally, hospital data can provide information on the injury patterns sustained by the accident victims. Figure 10 illustrates the distribution of body parts injured of the various road user types. Cyclists, for example, show a high proportion of injuries of the upper extremities.

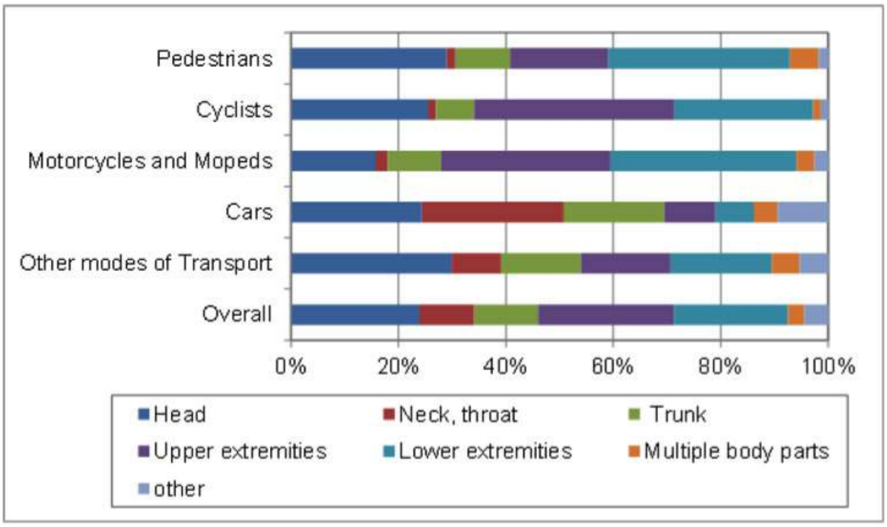



Figure 10: Body part injured, by mode of transport

Table 2 shows the types of injuries most frequently recorded in the EU IDB. It compares the distribution of injuries among cyclists to all types of road users. Here especially fractures and open wounds seem to be more common among cyclists than among other road users.

| | Cyclists | All modes of Transport |
|---|---|---|
| Contusion, bruise | 31% | 34% |
| Fracture | 34% | 27% |
| Open wound | 13% | 10% |
| Distortion, sprain | 6% | 8% |
| Concussion | 6% | 7% |
| Other specified brain injury | 2% | 2% |
| Luxation, dislocation | 3% | 2% |
| Injury to muscle and tendon | 1% | 2% |
| Abrasion | 1% | 1% |
| Injury to internal organs | 0% | 1% |
| Other specified types of injury | 3% | 6% |
| Total | 100% | 100% |

**Table 2: Types of injury in cyclists and all modes of transport**

# ADDITIONAL DATA FROM ACCIDENT INVESTIGATIONS IN SWITZERLAND

To reflect the bicycle and e-bike accident situation in Switzerland a study based on police-recorded accidents was conducted and published under the scope of COST Action TU1101. Accidents which occurred in the years 2011 and 2012 involving a total of 504 e-bikers and 871 bicyclists were analysed and numerous variables such as age distribution, type of accident, trip purpose, helmet usage and injury severity were investigated and compared. Additionally, national figures were compared to those of a rural and an urban environment.

The investigations showed that most e-bikers who were involved in an accident were 40-65 years old and thus older than most accident-involved bicyclists. Contrary to bicyclists, only few accidents with e-bikers below 23 years of age were reported. Moreover, it was determined that accident-involved e-bikers and bicyclists tend to be younger in an urban than in a rural environment. The analysis of the type of accident revealed e-bikers to be involved in single accidents most frequently, however, bicyclists sustained crossing accidents in most cases. Nationwide 52% of the accident-involved e-bikers wore helmets; in the rural area helmet usage was higher and in the urban environment it was less. Bicyclists wore helmets less frequently than e-bikers in all investigated areas. Regarding injury severity it was found that nationwide more than half of the 40-65 year old, accident-involved bicyclists (64%) and e-bikers (57%) were slightly injured, followed by severely injured (bicyclists: 26%, e-bikers: 36%) and uninjured (bicyclists: 9%, e-bikers: 7%); about 1% of bicyclists and e-bikers were fatally injured. Statistical analyses regarding the comparison of the injury severity distributions of e-bikers and bicyclists, however, lead to diverging results. Thus, it was suggested to include medical data in further investigations.

Moreover, it was concluded that bicyclists and e-bikers aged 40+ are at higher risk of sustaining severe injuries than bicyclists and e-bikers aged 0-39. With the underlying data, however, an investigation of relations between injury severity and helmet usage was inappropriate since police reports do not provide information on the localisation of injuries. Hence, the authors suggested to implement the injury localisation in police reports and to classify injury severity via (M)AIS.

# BICYCLING AND ALCOHOL AND ASPECTS ON HELMET USE

In order to study the relationship among alcohol use, head trauma, and hemet use among cyclists involved in an accident in Germany, a study based on German In Depth Accident Study (GIDAS) was conducted and was published [5, 4].

All cyclists from the GIDAS database who were involved in a road accident between 2000 and 2010 and submitted to an alcohol test were selected. According to the limit set by German law, alcohol tests were classed as positive if the blood alcohol concentration (BAC) was equal to or greater than 0.05 mg/l. In the years 2000–2010, a total of 4928 cyclists were involved in road accidents. Of these, 299 underwent an alcohol test following the collision. Alcohol test results were available for 242 cyclists, who were thus included in the analysis; the 57 cyclists whose alcohol test results were not known were excluded. The following variables were included in the analysis: BAC: over the limit (>=0.05 mg/l) or under the limit (<0.05 mg/l); helmet worn at the time of the collision: yes or no; age: 11–24 years, 25–64 years, 65+ years; gender: male or female; responsibility for the accident: of the cyclist alone, of the driver of the other vehicle alone, of both parties involved; use of cycle path: yes or no; type of accident: single vehicle accident (i.e. involving only the bicycle), collision with a motorised vehicle, collision with a non-motorised vehicle (or pedestrian); road conditions: dry or wet/slippery; area: urban or exta-urban; speed limit: <50 km/h or >=50 km/h; weather conditions: good or bad; day of the week: Monday–Friday or Saturday–Sunday; head trauma: yes or no; trauma to other parts of the body (neck, chest, abdomen, spine, upper extremities, lower extremities, other): yes or no; maximum accident injury severity (MAIS): 0, 1–2, 3+. Absolute and relative frequencies were used to describe the studied variables. Cyclists with BACs over and those with BACs under the prescribed limit were compared, as were cyclists wearing and those not wearing a helmet at the time of the collision; also individuals without head trauma (head AIS = 0) with those who suffered a head trauma (head AIS 1+) where compared. Comparisons were performed using a chi-square test, or Fisher's test when appropriate. Three logistic regression models were carried out to evaluate the association between cyclist's BAC, helmet use, and head trauma (dependent variables) and the following variables: helmet use, age, gender, responsibility, use of cycle path, type of accident, road conditions, area, speed limit, weather conditions, day of the week, and collision consequences (independent variables). Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated.

In all, 242 cyclists involved in road accidents and submitted to alcohol testing were analysed. Of these, 138 (57.0%) were over the prescribed BAC limit and 206 (85.1%) were not wearing a helmet at the time of the accident. Fifty-one (21.4%) were aged 11–24 years, 162 (68.1%) 25–64 years, and 25 (10.5%) 65+ years; most (88.4%) were males. In 55.9% of cases, the cyclist was entirely responsible for the accident, and in 16.8% the other road user was entirely responsible; in 27.3% of cases they were both partially responsible. It emerged that 164 cyclists (69.8%) were not using a cycle path at the time of the accident. In 24.4% of cases, the accident involved only the cyclist, whereas in 56.6% of cases the cyclist collided with a motorised vehicle and in 19.0% with a non-motorised vehicle. Most of the accidents occurred on a dry road (84.3%), in an urban area (80.9%), with a speed limit >=50 km/h (81.1%), in good weather conditions (90.9%), and on a weekday (74.8%). Slight injuries (MAIS = 1–2) were sustained by 194 (84.7%) of the cyclists, while severe injuries (MAIS 3+) were recorded in 14 cases (6.1%). Head injuries were sustained by 129 (56.6%), neck injuries by four (1.7%), chest injuries by 17 (7.4%), abdominal injuries by five (2.2%), and spinal injuries by nine (3.9%); 119 (51.7%) cyclists suffered injuries to the upper extremities and 98 (42.6%) to the lower extremities (Table 3).

Table 4 shows the percentages of cyclists who had a BAC 0.05 mg/l ("Intoxicated") in relation to the other variables considered. This analysis showed higher percentages of intoxicated cyclists among those who had not been wearing a helmet than among those who had been wearing a helmet (59.7% vs. 41.7%, $p = 0.044$); and among the males compared with the females (60.6% vs. 28.7%, $p = 0.001$). As regards the responsibility for the collision, the intoxication rate was 71.4% among those who were at fault, 52.3% among those who were partially responsible, and 20.0% among those involved in a collision caused entirely by the other party involved ($p < 0.001$). The percentage of intoxicated cyclists was 47.4% among those who collided with a motorised vehicle, 60.9% among those involved in an accident with a nonmotorised vehicle, and 76.3% among those involved in a single vehicle accident (i.e. one which involved no other party) ($p = 0.001$). The percentage of intoxicated riders was higher in the group of cyclists who sustained head injuries compared with those who did not (62.8% vs. 47.5%, $p = 0.021$) and lower among the cyclists who sustained injuries to the lower extremities compared with those who did not sustain such injuries (44.9% vs. 65.1%, $p = 0.002$).

Multivariate analyses (logistic regression models) showed that female riders were less likely to have consumed alcohol (OR = 0.23, 95% CI: 0.08–0.66); cyclists who did not wear a helmet were more likely to have consumed alcohol (OR = 2.41, 95% CI: 1.08–5.38); cyclists who were not responsible for the collision were less likely to have consumed alcohol than those who were partially responsible for the accident (OR = 0.22, 95% CI: 0.08–0.61). Cyclists involved in collisions with another vehicle, motorised or not, had a lower risk of suffering a head injury compared with those involved in single vehicle accidents (OR = 0.27, 95% CI: 0.12–0.62, and OR = 0.08, 95% CI: 0.03–0.22, respectively) (data not shown).

| | n | % |
|---|---|---|
| **BAC (mg/l)** | | |
| <0.05 | 104 | 57.0 |
| ≥0.05 | 138 | 43.0 |
| **Use of helmet** | | |
| No | 206 | 85.1 |
| Yes | 36 | 14.9 |
| **Age (years)** | | |
| 11-24 | 51 | 21.4 |
| 25-64 | 162 | 68.1 |
| 65+ | 25 | 10.5 |
| **Gender** | | |
| Man | 213 | 88.4 |
| Woman | 28 | 11.6 |
| **Guilty** | | |
| Ciclyst | 133 | 55.9 |
| Other | 40 | 16.8 |
| Both | 65 | 27.3 |
| **Use of cycle path** | | |
| No | 164 | 69.8 |
| Yes | 71 | 30.2 |
| **Collision partner** | | |
| Single accident | 59 | 24.4 |
| Motorized vehicle | 137 | 56.6 |
| Not motorized Vehicle | 46 | 19.0 |
| **Road conditions** | | |
| Dry | 204 | 84.3 |
| Wet/slyppery | 38 | 15.7 |
| **Area** | | |
| Urban | 195 | 80.9 |
| Extra-urban | 46 | 19.1 |
| **Maximum permitted speed (km/h)** | | |
| <50 | 45 | 18.9 |
| ≥50 | 193 | 81.1 |
| **Weather conditions** | | |
| Good | 220 | 90.9 |
| Bad | 22 | 9.1 |

| | | |
|---|---|---|
| **Day of week** | | |
| Monday-Friday | 181 | 74.8 |
| Saturday-Sunday | 61 | 25.2 |
| **Maximum Ais** | | |
| 0 | 21 | 9.2 |
| 1-2 | 194 | 84.7 |
| 3-6 | 14 | 6.1 |
| **Head trauma** | | |
| No | 99 | 43.4 |
| Yes | 129 | 56.6 |
| **Neck trauma** | | |
| No | 226 | 98.3 |
| Yes | 4 | 1.7 |
| **Thorax trauma** | | |
| No | 213 | 92.6 |
| Yes | 17 | 7.4 |
| **Abdomen trauma** | | |
| No | 225 | 97.8 |
| Yes | 5 | 2.2 |
| **Spine trauma** | | |
| No | 221 | 96.1 |
| Yes | 9 | 3.9 |
| **Upper extremity trauma** | | |
| No | 111 | 48.3 |
| Yes | 119 | 51.7 |
| **Lower extremity trauma** | | |
| No | 132 | 57.4 |
| Yes | 98 | 42.6 |
| **External and other trauma** | | |
| No | 227 | 98.7 |
| Yes | 3 | 1.3 |

**Table 3: Sample description**

| Variables | | Intoxicated (N=242) | |
|---|---|---|---|
| | n | N (%) | p |
| **Use of helmet** | | | 0.044 |
| No | 206 | **123** (59.7) | |
| Yes | 36 | **15** (41.7) | |
| **Age (years)** | | | 0.347 |
| 11-24 | 51 | **25** (49.0) | |
| 25-64 | 162 | **97** (59.9) | |
| 65+ | 25 | **13** (52.0) | |
| **Gender** | | | 0.001 |
| Male | 213 | **129** (60.5) | |
| Female | 28 | **8** (28.7) | |
| **Responsibility** | | | <0.001 |
| Cyclist alone | 133 | **95** (71.4) | |
| Other party alone | 40 | **8** (20.0) | |
| Both | 65 | **34** (52.3) | |
| **Use of cycle path** | | | 0.476 |
| No | 164 | **96** (58.5) | |
| Yes | 71 | **38** (53.5) | |
| **Type of collision** | | | 0.001 |
| Single-vehicle | 59 | **45** (76.3) | |
| With motorised vehicle | 137 | **65** (47.4) | |
| With non-motorised vehicle | 46 | **28** (60.9) | |
| **Road conditions** | | | 0.406 |
| Dry | 204 | **114** (55.9) | |
| Wet/slippery | 38 | **24** (63.2) | |
| **Area** | | | 0.053 |
| Urban | 195 | **105** (53.8) | |
| Extra-urban | 46 | **32** (69.6) | |
| **Speed limit (km/h)** | | | 0.861 |
| <50 | 45 | **25** (55.6) | |
| ≥50 | 193 | **110** (57.0) | |
| **Weather conditions** | | | 0.485 |
| Good | 220 | **127** (57.7) | |
| Bad | 22 | **11** (50.0) | |
| **Day of week** | | | 0.336 |
| Monday-Friday | 181 | **100** (55.2) | |
| Saturday/Sunday | 61 | **38** (62.3) | |
| **Maximum AIS** | | | 0.409 |
| 0 | 21 | **13** (61.9) | |
| 1-2 | 194 | **106** (54.6) | |
| 3-6 | 14 | **10** (71.4) | |

| | | | |
|---|---|---|---|
| **Head trauma** | | | 0.021 |
| No | **99** | 47 (47.5) | |
| Yes | **129** | 81 (62.8) | |
| **Neck trauma** | | | 1.000* |
| No | **226** | 128 (56.6) | |
| Yes | **4** | 2 (50.0) | |
| **Chest trauma** | | | 0.413 |
| No | **213** | 122 (57.3) | |
| Yes | **17** | 8 (47.1) | |
| **Abdominal trauma** | | | 1.000* |
| No | **225** | 127 (56.4) | |
| Yes | **5** | 3 (60.0) | |
| **Spinal trauma** | | | 1.000* |
| No | **221** | 125 (56.6) | |
| Yes | **9** | 5 (55.6) | |
| **Upper extremity trauma** | | | 0.945 |
| No | **111** | 63 (56.8) | |
| Yes | **119** | 67 (56.3) | |
| **Lower extremity trauma** | | | 0.002 |
| No | **132** | 86 (65.1) | |
| Yes | **98** | 44 (44.9) | |
| **Other** | | | 1.000* |
| No | **227** | 128 (56.4) | |
| Yes | **3** | 2 (66.7) | |

* Fisher's exact test

Table 4 Percentages of bicycle riders with a BAC >=0.05 mg/l by sample characteristics

# NATIONAL CYCLIST INJURY SITUATIONS DESCRIBED BY DATA PROVIDED BY COST PARTNERS

The following analysis on the bicycle accident situation of different countries is based on the data provided by the COST partners. It has to be kept in mind that the year of the data that was provided varies among the partners because it was not always possible to provide data for the last year 2013. Furthermore the definition of injury severity is not consistent among the different countries. Hence for some countries it is not possible to provide statistical data which distinguishes between slight and severe injuries at all.

Figure 11 displays the amount of cyclists killed per million inhabitants in the year 2011 in the counties of the COST-partners. The analysis shows similar values as the cyclist fatality rates in Europe which is based on the actual available CARE data (green columns). Minor differences may be explained by the different years of the data availability. Values range from 1.4 fatally injured bicyclists per million inhabitants in Greece to 6.5 fatally injured bicyclist per million inhabitants in Belgium. According to CARE-Data the Netherlands even have 8.3 6.5 fatally injured bicyclist per million inhabitants. The data concerning Greece was extrapolated from the values available from January 2010 to September 2010 to the year 2010 by applying the factor 4/3.

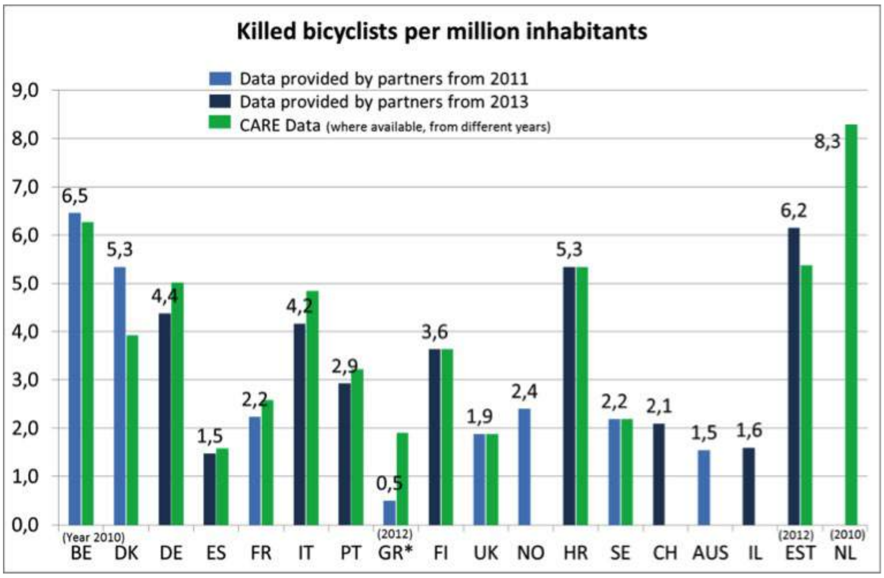



**Figure 11: Killed bicyclists per million inhabitants (Data provided by COST Partners).**

The percentage of bicycle fatalities from all road fatalities in the COST-Partner countries can be seen in Figure 12. The divergence to the values found in the CARE data (green columns) can possibly be assigned to the different years of accident data. With over 10% Denmark and Germany have the highest share of bicycle fatalities of all road fatalities among the COST partner countries. However Netherlands, not being a COST partner country, has an even higher share of bicycle fatalities from all road fatalities with 21% (according to CARE data). The low share of bicycle fatalities in Greece with only 0,5% according to the Hellenic statistical authority may be explained with low cycling rates among the population.

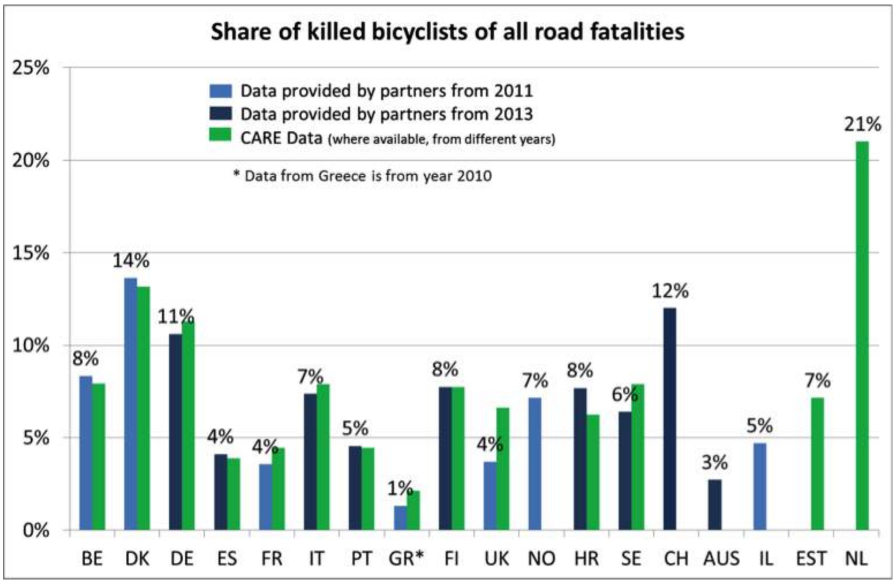



Figure 12: Share of bicycle fatalities of all traffic fatalities in the different countries of the COST partners (Data provided by COST Partners).

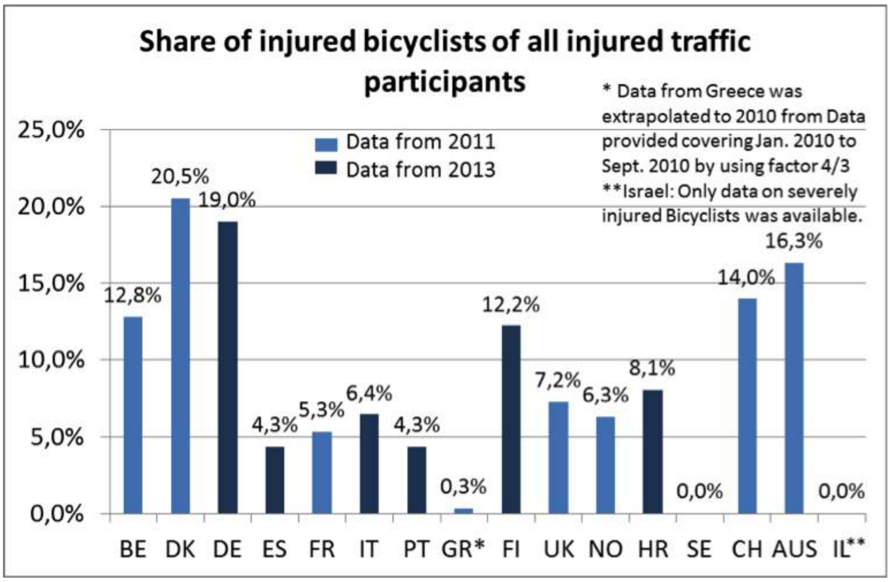



Figure 13: Share of slightly injured bicyclists of all slightly injured traffic participants in the different countries of the COST partners (Data provided by COST Partners).

Due to the fact that the injury severity is not known in some countries the total of all injured bicyclists is compared to all injured traffic participants in Figure 13. Here again some significant differences between the countries are visible: 20% of the slightly injured traffic participants in Denmark and 19 % in Germany were bicyclists. In contrast in Spain and Portugal just over 4% of the slightly injured traffic participants were cyclists. The extraordinary low share of Greece could by explained with underreporting of slight injuries. As from Israel only data of severely injured cyclists were available, no figure was included in the analysis. Additionally the share of severely injured cyclists of all injured cyclists is displayed in Figure 14. The values of some countries could not be added as no data was available distinguishing between slight and severe injuries. In Denmark 61% of the injured cyclists are severely injured while in Portugal (5%) and in Greece (3%) the absolute minority of injured cyclists are severely injured. The differences must certainly also be seen in the context of different definitions concerning slight and severe injuries among the different countries.

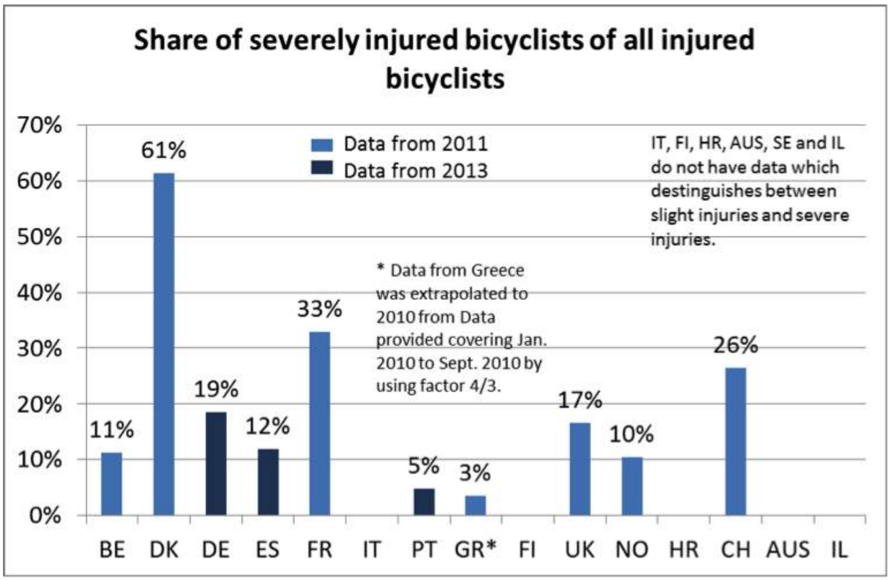



**Figure 14: Share of severely injured bicyclists of all severely injured traffic participants in the different countries of the COST partners (Data provided by COST Partners).**

The helmet wearing rate is a figure which not all countries could provide as it cannot be taken from accidents statistics and usually requires an additional study. When comparing the helmet wearing rates of the countries that could provide some data it has to be kept in mind that the data was often taken from national studies which were conducted or published sometimes as far back as the year 2008. Furthermore the wearing rate was collected in a different manner. For example a French study has distinguished between riders that always wear helmets (14%) and riders that never wear helmets (77%) and in the UK the wearing rate was distinguished between riders on major roads (34% wearing rate) and on minor roads (17% wearing rate) and in Sweden the wearing rate was estimated as a combined figure from different age groups. In Greece the helmet wearing rate was determined by self-reported helmet use (never, rarely, sometimes, often, always) of riders for different trip destinations (going to work/school, riding at work/school, going to a bar/ night club, riding without a specific destination, going shopping)[6, 7]. The study revealed that the most frequently reported destination/place where bike riding occurred was "when riding without a specific destination" with a mean of 2.7 on a scale from 0=never to 4=always. The self-reported helmet wearing rate here was 1.4 on the same scale. Other trip destinations had lower wearing rates from 0.2 while at work to 0.6 when going to work/school. The helmet wearing rate in Switzerland is determined by observation of over 6000 cyclists in 67 different counting points. In 2013 the wearing rate increased to 46% from 43% in 2012 and 40% in 2011. Among the e-bike riders in Switzerland however 74% wore a helmet and among the users of fast e-bikes a helmet wearing rate of 88% was investigated.

When comparing the available percentages of helmet wearing rates from the different countries (Figure 15), large differences can be found. In Italy it is assumed that in average only 3% of the bicycle riders wear helmets and in Germany only 9% wore a helmet according to a study from 2011. On the other hand in Australia where wearing a bicycle helmet is mandatory some 89% of bicycle riders wear a helmet according to self-report in a population survey of old adults and in Israel even 94% of the riders wear helmets. A study on e-bike accidents from 2011 and 2012 in Switzerland [8] revealed that nationwide about 52% of accident-involved e-bikers wore helmets. In the rural area helmet usage was higher and in the urban environment it was less. Bicyclists wore helmets less frequently than e-bikers in all investigated areas.

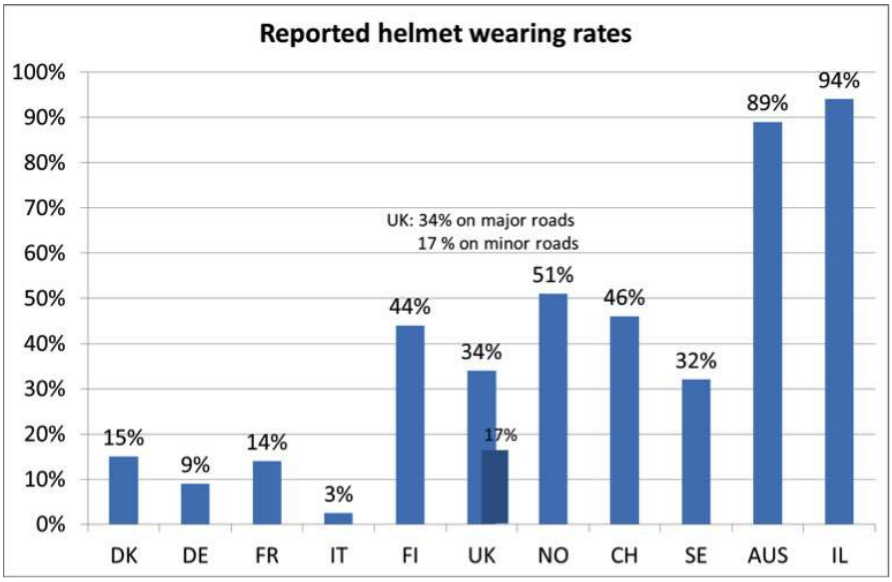



**Figure 15: Reported helmet wearing rates from different years (between 2008 and 2013) in the different countries of the COST partners (Data provided by COST Partners, Helmet wearing rates were not available for all countries).**

An overview over the bicycle helmet legislation in different countries worldwide was taken from the Wikipedia website [9] and can be seen in the following Table 5. For many countries no information was available which often means that no helmet wearing requirements are in place. The situation outside Europe is that in Australia and New Zealand the helmet use is mandatory by law for all bicyclists since 20 years and more [10]. In South Africa and Dubai (UAE) a mandatory use of bicycle helmets was introduced more recently, in this millennium, however in South Africa the law is not enforced as no fines apply. A mandatory helmet use for certain age groups (mostly children) is the case in Israel, Japan, South Korea. In the US and in Canada helmet wearing regulations depend upon state law. In some states wearing bicycle helmets is mandatory for all bicyclists and in some states it is mandatory only for certain age groups. On the other hand Mexico has repealed its mandatory helmet laws in 2010 and Hong Kong has introduced that there is no intention of introducing a mandatory helmet law, based partly on international views that a mandatory requirement may lead to a reduction in cycling activities.

| European Countries | Date enacted | Notes |
|---|---|---|
| Austria | 2011 | Under 12 years of age only. |
| Czech Republic | | Mandatory for cyclists under 18 years. |
| Croatia | 2008 | Under 16 years of age only. |
| Denmark | | Not mandatory, however under discussion in the Parliament, for a future implementation of the relevant legislation for children under 15 years of age (https://www.cyklistforbundet.dk) |
| Estonia | | Mandatory for cyclists under 16 years cycling when riding on the road. |
| Finland | 2003 | Mandatory but not enforced (no fine). |
| France | | Recommended for children |
| Hungary | | Mandatory outside built-up areas riding on roads where speeds are higher than 50km/h. |
| Ireland | | Recommended |
| Iceland | 1998 | Under 15 years of age only. Iceland has considered - but not pursued - extending its helmet law to adults. |
| Latvia | | Mandatory for children. |
| Lithuania | | Mandatory for cyclists under 18 years. |
| Malta | | Mandatory for power assisted pedal cycles and for children under 10 travelling pillion in a safety seat. |
| Slovenia | 2000 | Mandatory under 15 years of age. |
| Slovakia | | Mandatory for cyclists under 15 years and all cyclists outside built-up areas. |
| Spain | 2004 | Required on interurban routes except when going uphill or in very hot weather, or for professional cyclists. Mandatory for cyclists under16 years. |
| Sweden | 2005 | Only applicable to children under 15 years old. No penalty for children cycling alone who do not obey the law. |
| United Kingdom | | Recommended |

| Non-European Countries | Date enacted | Notes |
|---|---|---|
| Australia | 1989 | Between 1990 and 1992, Australian states and territories introduced various laws mandating that cyclists wear bicycle helmets. Australia was the first country to make wearing bicycle helmets mandatory |
| Canada | 1995 - New Brunswick<br>1995 - Ontario*<br>1996 - British Columbia<br>1997 - Nova Scotia<br>2002 - Alberta*<br>2003 - Prince Edward Island<br>2013 - Manitoba* | In Alberta, Manitoba and Ontario only applies to cyclists under 18 years of age. In 2007 the Saskatoon (Saskatchewan) city council voted against mandatory helmet use. |
| Hong Kong | No requirement | In 2009, Transport Secretary announced that government had no intention of introducing mandatory helmet law, based partly on "international views that a mandatory requirement may lead to a reduction in cycling activities." |
| Israel | 2007 | Not enforced. Starting from 2011, only applies under 18 years of age, in interurban ways and during sport events. |
| Japan | 2008 | Under 13 years of age only.] |
| New Zealand | 1993 | Bicycle helmets have been mandatory in New Zealand since January, 1994. |
| Singapore | | Only power-assisted bicycle on a road |
| South Africa | 2004 | Compulsory for all cyclists but in practice the law is not enforced. No fine had been agreed. |
| South Korea | 2006 | Under 13 years of age only. |
| United States | Varies by state | The requirement to wear bicycle helmets in the United States varies by jurisdiction and by age of the cyclist. Twenty-one states and the District of Columbia have state wide mandatory helmet laws for children.[2] Twenty-nine US states have no state wide law, and 13 of these states have no such laws in any lower-level jurisdiction either. |

**Table 5: Overview over the bicycle helmet legislation in different countries (Mostly from Wikipedia: http://en.wikipedia.org/wiki/Bicycle_helmet_laws_by_country and from ETSC http://etsc.eu/wp-content/uploads/etsc_pin_flash_29_walking_cycling_safer.pdf ).**

For Europe the ETSC report "The Safety of Vulnerable Road Users in the Southern, Eastern and Central European Countries (The SEC Belt)" states that cycle helmets reduce fatal and serious injuries by between 45 and 80% according to several studies [11]. The use of bicycle helmets is (with a few notable exceptions) only encouraged in the SEC Belt countries. The exceptions are Malta, Spain, Slovenia, Czech Republic and Portugal: bicycle helmets have become mandatory in Malta in April 2004 and are compulsory in Spain outside urban areas (with one exception: cyclists do not need to wear a helmet when they are going uphill). In Sweden, Slovenia and the Czech Republic cycle helmets are compulsory only for children up to 15 years of age and experience shows that bicyclists stop using them. Portugal has introduced compulsory bicycle helmets at the beginning of May 2004 but the timescale for application of the new law is not clear yet.

In the remaining eleven countries of the SEC Belt, which do not require the use of helmets by law, the wearing rate is normally very low (less than 10%) Also, in Poland an attempt was made in 2002 to introduce mandatory use but the proposed measure had to face an opposition from the cyclists' organizations who believed such a measure would have constituted a deterrent to bicycle use. Critics of legislation, though, have pointed out that reductions in absolute numbers of cycling fatalities and severe head injuries can be at least partially explained by a decrease in cycling per se.

Towner et al. [12] have summarized the pros and cons of bicycle helmet legislation as follows: The pro-bicycle helmet group base their argument on the fact that there is scientific evidence that, in the event of a fall, helmets substantially reduce head injury.

The anti-helmet group base their argument on several issues including: compulsory helmet wearing leads to a decline in cycling, risk compensation theory negates health gains, scientific studies are defective, and the overall road environment needs to be improved.

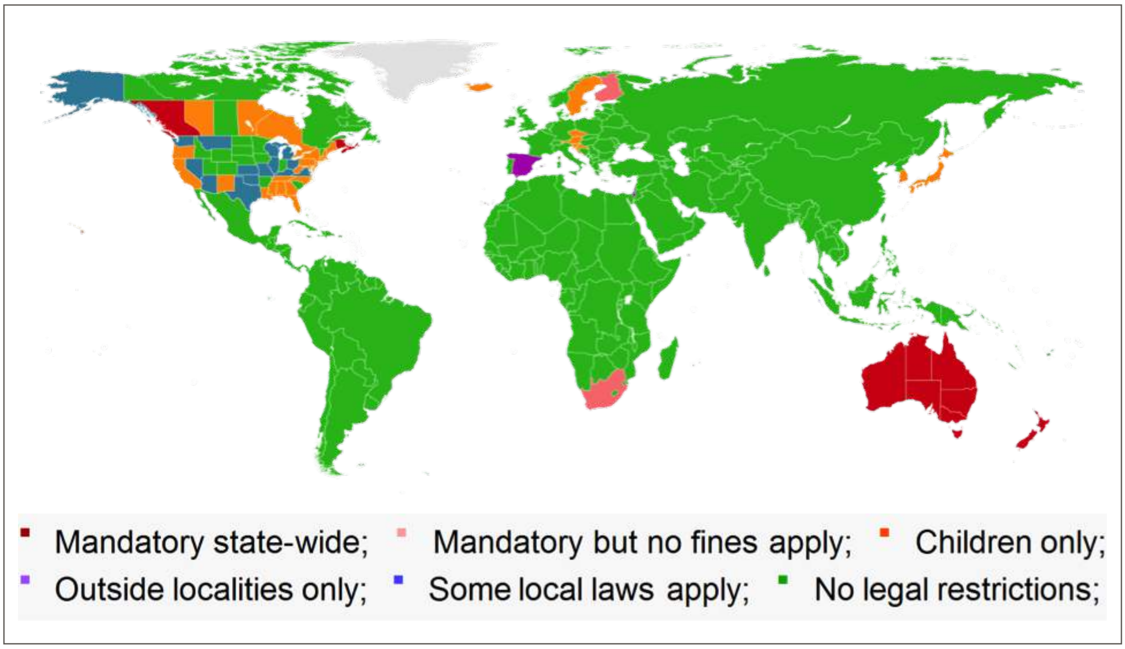



**Figure 16: Helmet wearing regulations in different countries of the world (from Wikipedia).**

The world map in Figure 16 displays the distribution of helmet wearing regulations in the different countries. The majority of the countries worldwide do not have mandatory helmet wearing regulations in place.

## CONCLUSIONS FROM INJURY DATA ON CYCLISTS

The statistical data on bicycle accidents in Europe was analysed by using the bicycle basic-fact-sheets based on CARE data and by using data provided be the participants of WG1. It can be seen that the cyclist fatalities were decreasing between the years 2001 and 2010 in Europe. However there is a difference between the European countries, as such the fatality (fatalities per million inhabitants) varies from 1 (Ireland) to over 8 fatalities per million inhabitants in Netherlands, Romania and Hungary. Furthermore in Denmark for example over 75% of cyclist fatalities occurred in urban areas, while only 26% occurred in urban areas in Spain.

Accoding to the EU Injury Database IDB 32% of road accident casualties recorded in the database were admitted to the hospital overall, while this was the case only for 23% for cyclists. Cyclists especially suffered from fractures and open wounds more frequntly than other road users.

Based on the national statistical data provided by the COST partners the injury situation of was compared and revealed major differences between the countries concerning the share of injured bicyclists of all injured traffic participants for reasons such as underreporting. It has to noted that comparability here is difficult due to different definitions concerning slight and severe injuries among the different countries. The reported helmet using rate in the different European countries varies from 3% in Italy to over 50% in Norway, if looking to all age groups of bicyclists. The highest rate can be seen for children, as in some countries like Austria or Sweden a mendatory use of the helmet is established for children. There is also no standard procedure for collecting helmet usage rates. This fact and the representativity of a subsample chosen to define helmet usage rates make it difficult to compare the true helmet wearing rates in different countires

An overview over the bicycle helmet legislation in different countries worldwide shows that for many countries no information was available which often means that no helmet wearing requirements are in place. In some countries there is a mandatory helmet use for certain age groups (mostly children). Some countries however state that there is no intention of introducing a mandatory helmet law, based partly on international views that a mandatory requirement may lead to a reduction in cycling activities.

# B. IN-DEPTH ACCIDENT ANALYSIS OF HEAD INJURIES AND THE EFFECTIVENESS OF THE BICYCLE HELMET IN REAL ACCIDENT SITUATIONS

The effectiveness of bicycle helmets in accidents is described quite differently, but largely positively in scientific literature. .A study by Maimaris et al. [13] in the UK determined that 4% of the wearers of bicycle helmets suffered head injuries in contrast to 11% of those not protected by helmets, whereas an Australian study by McDermott [14] compared the fatality rates of helmet wearers (0.4%) to those not wearing helmets (0.9%), upon which he based his postulate of the effectiveness of bicycle helmets as injury prevention devices. Studies have also found a reduction of facial injuries due to a bicycle helmet. Wesson et al. [15] described a reduction of injuries of the upper facial area, whereas no reduction of injuries to the lower facial area had occurred. This was also confirmed by Rivara et al. [16]. However, there are also studies that question the effectiveness of bicycle helmets in accidents. There is an argument also, that not all types of standard bicycle helmet protect against injury to the brain [17]. In particular, the Australian studies by Voukelatos et al. [18] have to be mentioned in this context, they are based on the annual representation of the ratio of arm and head injuries in conjunction with the date when helmet use became mandatory, and which postulate no indication of the effectiveness of bicycle helmets as potential protection. He assumed that helmet use should lower this ratio as an indicator of the effectiveness of helmets. If this ratio value is regarded over time, however, it becomes obvious that in Australia (and also in New South Wales) this ratio decreased continuously from 1985 to 2000, whereas the helmet use for cyclists became mandatory only in 1990, and a total of 3 years passed until 100% of the bicyclists were in fact using a helmet. One explanation is derived from the fact that other measures such as the influence of road safety through planning measures are more effective than wearing a bicycle helmet. In this context UK publications concerning the influence of a mandatory wearing of bicycle helmets are interesting. Walker [19] found that drivers of cars and trucks passed closer to cyclists if they wore a helmet and kept more distance if no helmet was worn. Studies by Adams et al. [20] confirm this influence of the helmet and name risk compensation as the cause of a negative consequence of a practical implementation of a security measure, which analogous to the introduction of the seat belts and motorcycle helmets, now applies to bicycle helmets, negating a protective effect. Wearing a helmet may affect the behavior of the wearer in traffic and can therefore cause a higher risk of accidents. In contrast, many studies showed that an increase in the frequency of wearing bicycle helmets due motivating campaigns resulted in a significant decrease in head injuries in cyclists [15, 16, 21]. The effectiveness of bicycle helmets in literature is often discussed in conjunction with mandatory helmet use, for that reason there are a few studies that specifically show the effectiveness of the helmet in relation to injuries sustained and a scientific assessment of the protective potential of helmets in view of certain injury patterns to the head. In particular in Germany, there are few studies on the effectiveness of bicycle helmets, since as yet there is little helmet use, which does not permit statistical comparisons of wearers of helmets with those without a helmet and therefore are mostly exploratory and were conducted using single randomization, for which usually no control groups were available. Only recently have results for the effectiveness of helmets appeared based on accident analyzes for Germany. A study by the insurance company Allianz Versicherung published in 2013 [22], which advocates the use of bicycle helmets noting that seniors constitute 51 % of all pedestrian and cyclists fatalities, one third of all bicycle accidents without involving third parties are falls and the number of unreported cases is very high, which means they are not included in the accident statistics. A study by the Universitätsklinik Münster published in 2012 [23] also points that way. Kroemer et al. [24] carried out a pilot study for Austria on this subject and estimated their number at 1.6 million for the EU.

The following statistics extracted from GIDAS data that had been collected at the sites of accidents were weighted to reflect the entire accident landscape in Germany. The accident statistics of Germany of the year 2011 published by the Federal Statistical Office [25] were used as reference data. Weighting factors were the local situation (inside/outside of built-up areas) and the injury severity (slightly injured, seriously injured, and killed). That way resulted in a two-dimensional table for six different factors. Used these for all the dataset the results can be pointed out as representative for the country.

# ACCIDENT AND INJURY PATTERNS OF BICYCLISTS

Approximately 69% of all collision partners in road accidents involving bicyclists are cars, both for cyclists with and without helmets. Approximately 10% of all collisions occur without the influence of other traffic participants. The fact that 8% of the collisions involved other cyclists is also noticeable. Figure 17 shows the distribution of the collision parties of injured bicyclists. There is no difference between the groups with and without helmets.

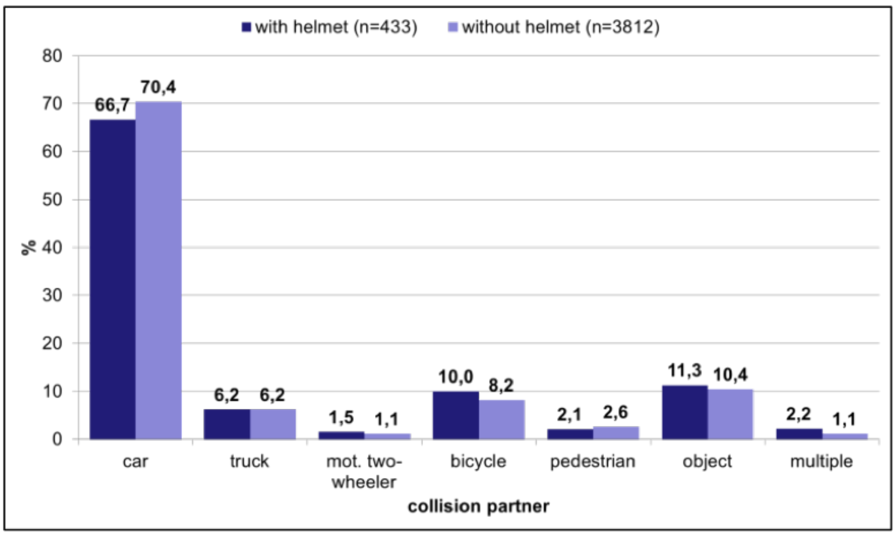



**Figure 17: Percentage distribution of the collision partners of injured cyclists with and without helmet.**

This is also confirmed by Figure 18, which shows the cumulative frequency of the detected collision speeds of the collision partner of the bicyclists with and without helmets. 80% of the collision velocities of vehicles colliding with a bicycle were registered at below 26 km/h and 10% of the impact velocities occurred at speeds above 35 km/h. Thus the comparison of the two groups with and without helmets may be expected to yield results that are free of distortions and confirms the relatively same frame conditions of the compared groups.

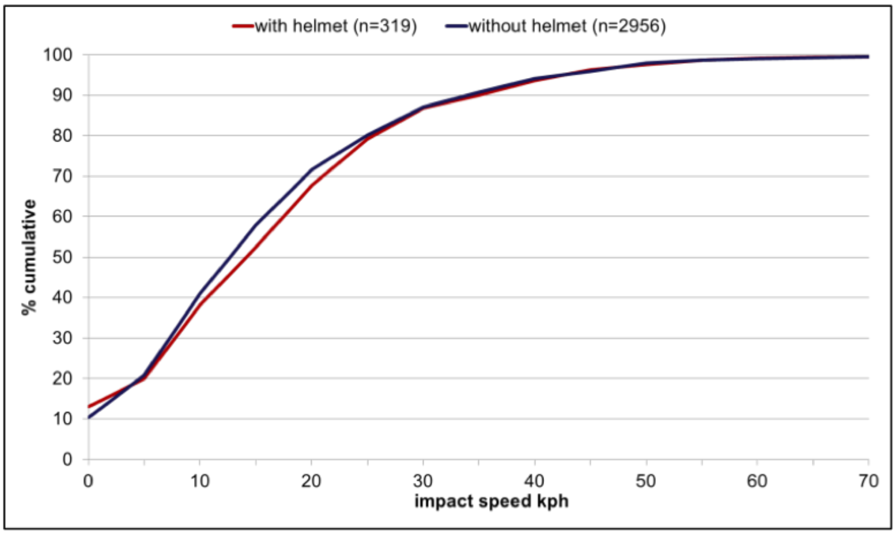



**Figure 18: Comparison of the cumulative frequency of collision speeds of the collision partner of the injured cyclists with and without a bicycle helmet.**

It turns out that approximately 74% of all cyclists suffered injuries of severity MAIS 1, i.e. they were only slightly injured (Figure 19). Differences between wearers of helmets and those without helmet occurred in particular for the higher injury severity levels, which occurred only rarely in bicyclists wearing a helmet. 0.3% of the 3,812 bicyclists without a bicycle helmet suffered severe injuries AIS 5/6. 3.5% of the bicyclists with and without a bicycle helmet suffered injuries MAIS 3 and 4. It would be easy to assume a change due the helmet in relation to the higher proportion of MAIS 2 injuries amongst wearers of helmets (21.2% with helmet versus 17.5% without). If the overall injury severity MAIS is considered, however, injuries to other body regions may be more common. For that reason, the overall severity of the injuries to the particular body regions with and without helmet is shown in Figure 8.

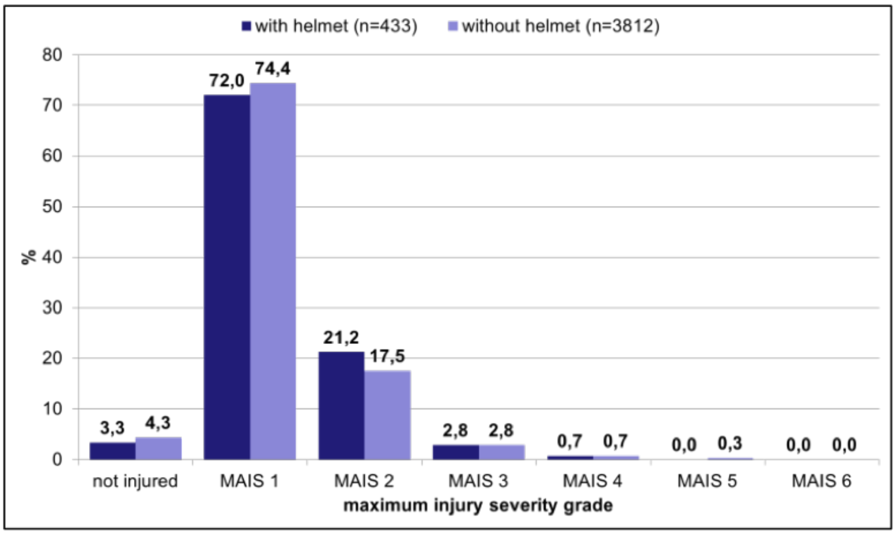



**Figure 19: Percentage distribution of the overall severity of the injuries (MAIS) of injured cyclists with and without a helmet.**

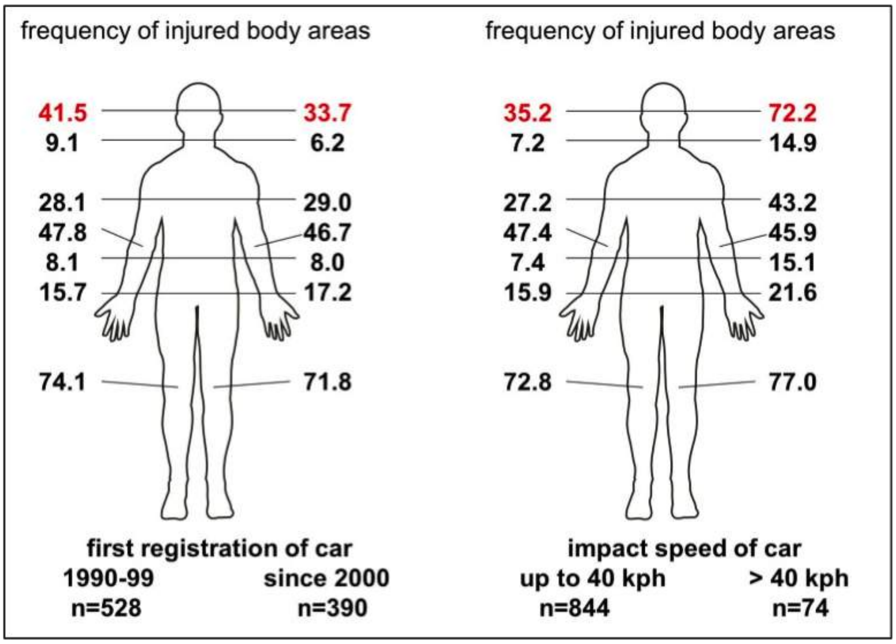



**Figure 20: Percentage of injured body regions differentiated according to the year of manufacture of the vehicles having collided with the bicyclist (old: model years 1990 to 1999, new: build after 2000) and two ranges of collision speeds of the cars in collision with cyclists (up to 40 km /h versus above 40 km/h).**

Figure 20 differentiates on the one hand between the years the passenger car was built (before 2000 versus from 2000 onwards) and the impact of the collision velocity of the cars (up to 40 km/h versus above 40 km/h) for the proportion of injured body regions of bicyclists involved in accidents. For impact speeds of up to 40 km/h, 35.2% of the cyclists suffered head injuries, whereas this happened to 72.2% at speeds above 40 kph. Newer vehicles can be asseverated to induce fewer head injuries in comparison to older models (33.7% versus 41.5%). A particularly striking influence of vehicle speed on the incidence of injuries was demonstrated for head injuries (35.2% versus 72.2%), but for virtually all other regions of the body an increase in speed is accompanied by an increase of injuries.

# INJURY SEVERITIES OF THE HEADS OF BICYCLISTS INVOLVED IN AN ACCIDENT

Severity of head injuries can be classified scientifically as AIS head (Figure 21) based on the Abbreviated Injury Scale (AIS). It is obvious that wearing a helmet shifts high injury severity degrees towards lighter degrees and even uninjured states. 70.2% of the cyclists with bicycle helmet remained uninjured (versus 61.9% without helmet), 18.1% suffered minor injuries AIS 1 (versus 27.7% without helmet), 11.1% moderately severe injuries AIS 2 (versus 8.8% without helmet). Higher injury severities AIS 3 + occurred in only 0.6% of the helmet wearers, in contrast to 1.6% of the 3,812 cyclists without a helmet that had been involved in an accident (equivalent to a decrease of 62.5%).

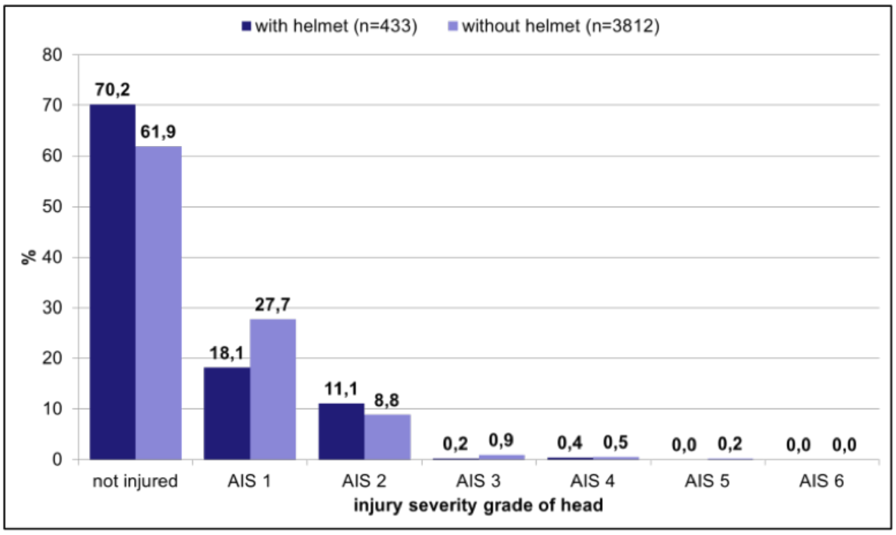



**Figure 21: Percentage distribution of head injury severity levels for injured cyclists with and without helmets.**

For illustrative purposes Figure 22 below shows the severity of the head injuries without facial injuries because, due to the nature and design of the helmet, the face of the helmet wearer is not (fully) protected. For the comparison the protected areas only, 0.2% of helmet wearers suffer from injuries to the head AIS 3+, in contrast to 1.6% for cyclists without a helmet (this corresponds to a decrease of 87.5%).

Head injuries of AIS 2 occur at slightly higher percentages in wearers of helmets than in cyclists without a helmet. It may be postulated here that the protective effect of the helmet causes a shift of the severe AIS 3+ injuries towards the lighter AIS 2 injuries. Also significantly fewer injuries AIS 1 occurred with helmet (4.7% as versus 12.8% without helmet). This percentage correlates approximately with the higher proportion of uninjured cyclists wearing a helmet.

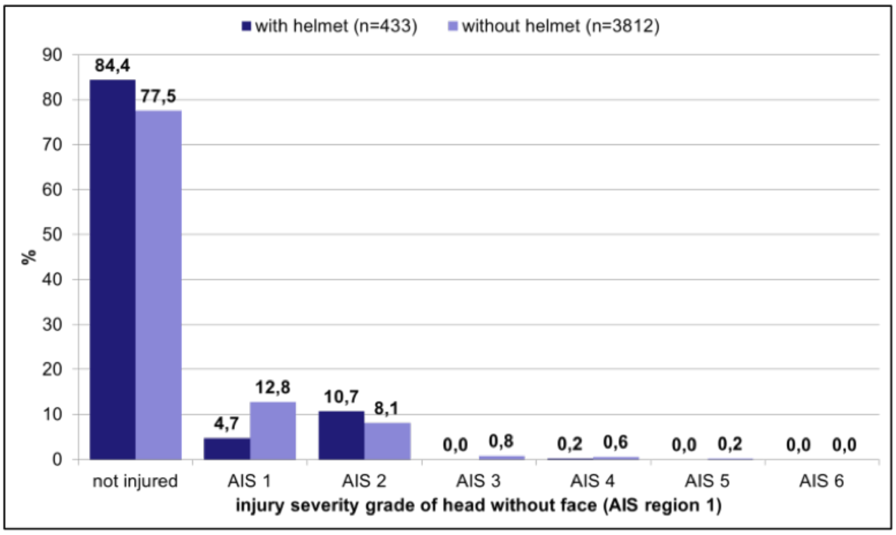



**Figure 22: Percentage distribution of head injury severity levels (excluding the face) for injured cyclists with and without helmet.**

# EFFECTIVENESS OF THE BICYCLE HELMETS

If the head injury severity and helmet use are considered as a function of the age of the cyclists (Figure 23) and if the injury severities are grouped for different age groups according to AIS head, a substantial influence of age on the occurrence of head injuries emerges, but also a substantial influence of a helmet on the origin of the injury. The increase in severe head injuries of the severity AIS 3+ is particularly obvious without helmets. Based on the higher probability of occurrence of injuries with increasing age, which can be explained biomechanically, the increase in head injuries AIS 3+ is also visible in older people. The comparison with bicyclists wearing helmets does not show such an increase. From the age of about 50 years, the effectiveness of a bicycle helmet appears to be more effective in reducing the severity of head injuries.

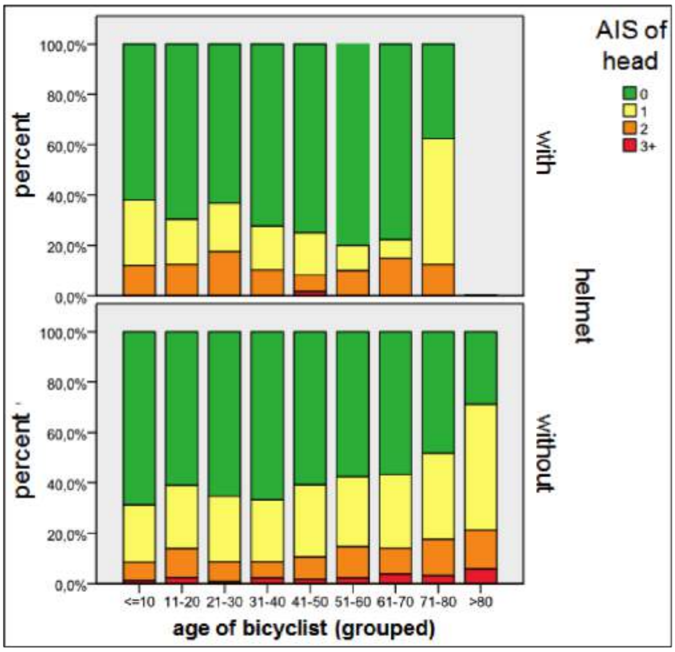



**Figure 23: Comparison of AIS head injuries according to group classification for different age groups subdivided for injured cyclists with and without helmets.**

Soft tissue injuries prove to be the dominant types of injuries (Figure 24), they were observed in 1/3 of all head injuries without a helmet (34.3%), in contrast to only 22.9% with helmet. This corresponds to a computed reduction by 33%. Traumatic brain injury can be differentiated into skull fracture (0.2 % versus 1.0% with helmet vs. without helmet, corresponding to a reduction by 80 %), brain injury AIS 3+ (0.2% with a helmet vs. 1.6% without a helmet, 88% reduction) and skull-base fracture (0.2% with a helmet vs. 0.8% without a helmet, 75% reduction). Virtually no injury reduction resulted for facial fractures (2.6% versus 2.7%). Brain injuries AIS 2 occurred slightly more often with a helmet than without a helmet. One explanation in relation to the facial fracture is based on the significance of the result in relation to the small numbers of cases, at any rate the surveys do not show a protective effect where facial fractures are concerned. Related to the brain injuries classified as AIS 2, an obvious increase in injured cyclists wearing helmets can be propounded, as this classification also covers the so-called commotio cerebri, better known as a concussion of the brain. This can, if a helmet is worn, even be more pronounced in the presence of a low overall head injury severity, as seen in cyclists wearing a helmet, than in conjunction with extensive injuries to the head and thus even occurs less frequently in those not wearing a helmet.

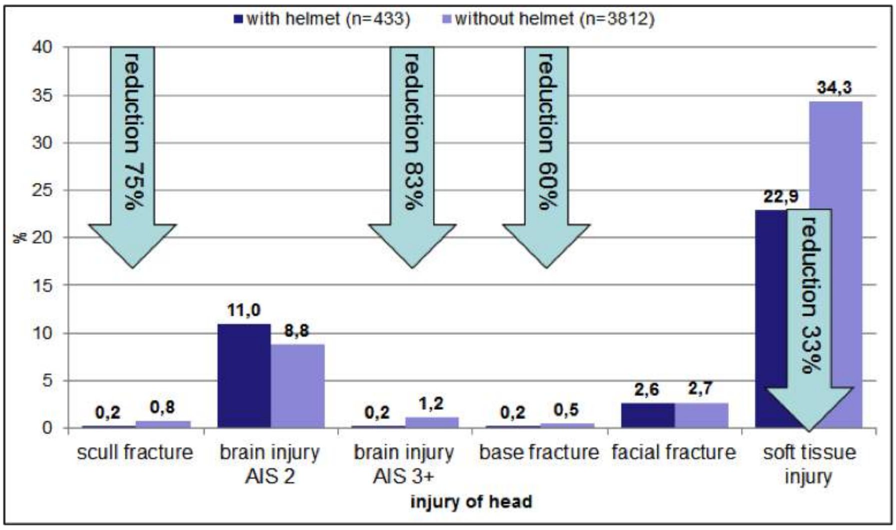



**Figure 24: Percentage of the types of head injuries in cyclists involved in accidents with and without a helmet (100 % each, all individuals with/without helmet).**

# DETERMINATION OF THE STATISTICAL PROBABILITY OF HEAD INJURIES AND EVALUATION OF THE INFLUENCING PARAMETERS ON THE SEVERITY OF HEAD INJURIES

A logistic regression was conducted to assess the relationship of accident parameters including use of helmets, age, sex, BMI, location, time of day, type of bicycle, use of bike paths, collision partner/type of accident (bivariate analyzes, cf. Table 6). The Chi² test in accordance with Pearson was used to determine the significance and the odds ratio used to indicate the probability of the event occurring and was used based on the evaluation of the target variable AIS head. It was demonstrated that the collision speed of the opponent as well as the age of the bicyclist, the location, the use of bike paths and the collision partners, in particular the solo accident are highly significant influencing parameters. Wearing a helmet is at p=0.0005 and an odds ratio of 1.503 also highly significant to the resulting injury severity. BMI, time of day, type of bicycle, collision partners (with the exception solo accidents), and gender, however, do not constitute significant influencing parameters.

| | | Odds Ratio | p |
|---|---|---|---|
| impact speed collision partner | | 1.035 | <0,0001 |
| age of bicyclist | | 1.011 | <0,0001 |
| BMI | | 1.000 | 0.9856 |
| accident location | rural | 2.131 | <0,0001 |
| daytime | dust<br>night | 1.132<br>1.298 | 0.9580<br>0.0950 |
| type of bicycle | BMX<br>bicycle n.f.s.<br>mountainbike<br>racing bicycle | 1.649<br>1.004<br>1.115<br>1.049 | 0.2106<br>0.1711<br>0.8066<br>0.5529 |
| cycle path | none, not used | 1.463 | <0,0001 |
| collision partner | single vehicle accident | 1.469 | <0,0001 |
| | bicycle<br>pedestrian<br>truck<br>multiple<br>mot. two-wheeler | 0.902<br>0.750<br>1.577<br>1.133<br>0.908 | 0.0589<br>0.0339<br>0.0069<br>0.9952<br>0.3799 |
| gender | female | 1.066 | 0.9587 |
| helmet | without | 1.503 | 0.0005 |

**Table 6: Odds Ratio of possible influencing parameters relative to the target variable AIS head (n=4,245).**

# DAMAGE PATTERN ON THE HELMET

As the helmets used by bicyclists have been developed in accordance with the current test guidelines CEN EN 1078 [26], the documented accidents are also being used with regard to the damage to the helmet in order to be able to assess the damage image and the stress image of the helmet in the accident. To this end, detailed photos were taken at the sites of the surveys and descriptions of the helmets damaged in the course of accidents were prepared, which have been documented in a damage matrix for each case. This matrix permits a detection of smears or abrasions on the outer shell of the helmet, deformations or breakage of the helmet shell and of the inside of the helmet material. The damage patterns recorded on helmets worn in the course of accidents are shown in Figure 25, Figure 26 and Figure 27, including data on the incidence of these occurrences. The green markings show the incidences of smears and abrasions, the yellow ones indentations and deformations and the red ones breakages.

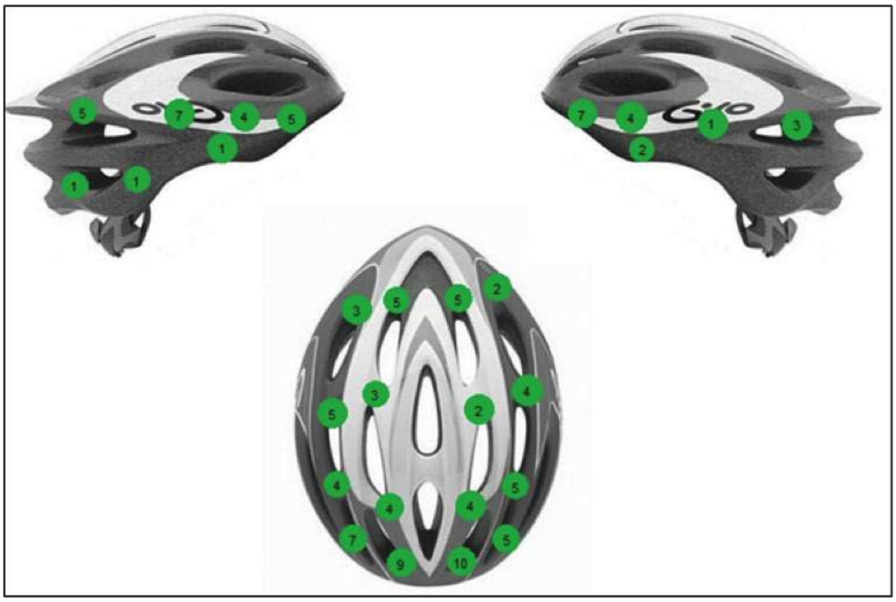


Figure 25: Damage matrix on helmets (smears / abrasions), representation of the location of damage to the helmet shell (specified as n-impact).

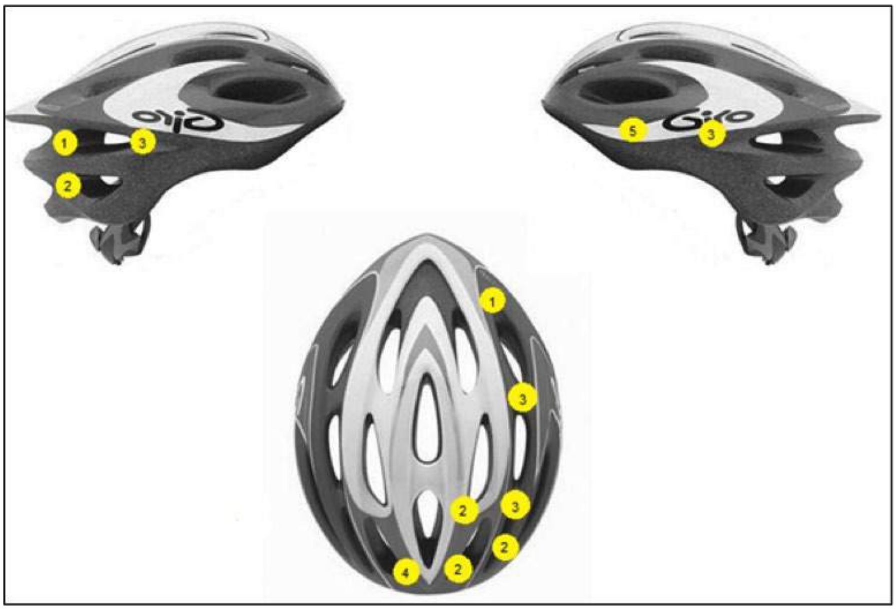


Figure 26: Damage matrix on helmets (deformations / indentations), representation of the location of damage to the helmet shell (specified as n-impact).

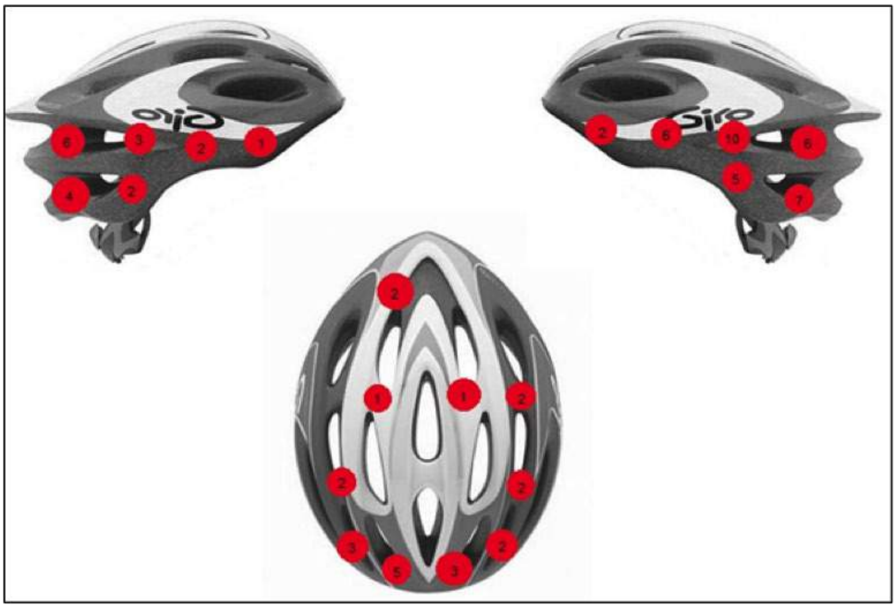


Figure 27: Damage matrix on helmets (breakage), representation of the location of damage to the helmet shell (specified as n-impact).

The predominant damage to the helmet can be found at the lateral edges/rims. In particular the breaking points, which represent the effectiveness of the transformation of high impact energies, can be located particularly often in the lateral edge and also in the upper lateral top part. No damage was found, however, exactly in the top centre of the helmet.

The different impact conditions of the head were analyzed regarding the surface of the impact zone. It could be established that 88.3% of all head impacts happened on a flat surface while 11.7% happened on an edgy surface (see Figure 28). The majority of the edgy impacts occurred from impacts against edgy parts from cars and trucks.

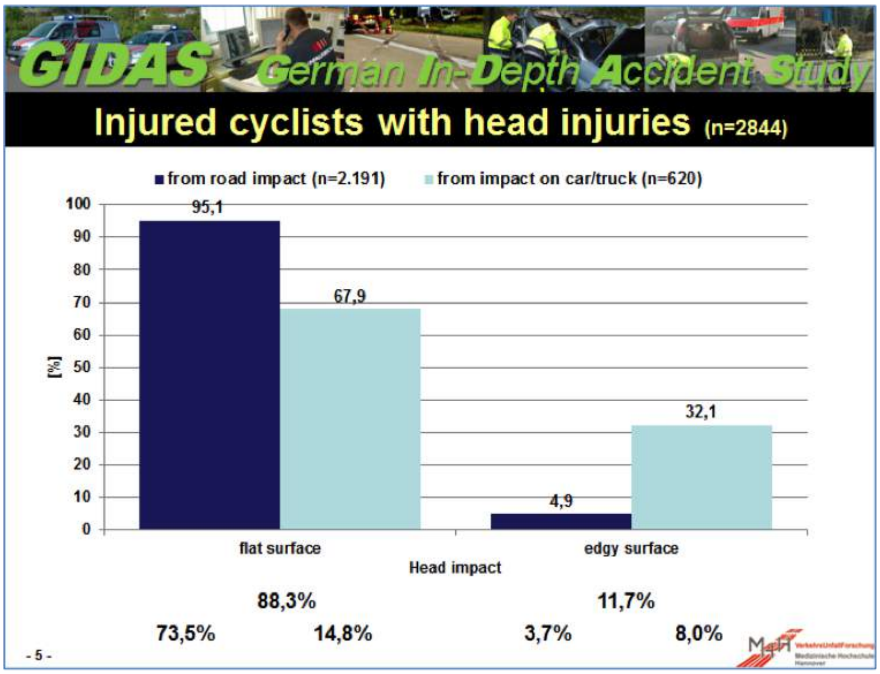



Figure 28: Surface types of head impacts of cyclists

# CONCLUSION FROM THE ACCIDENT STUDY

The wearing rate of bicycle helmets is very low in nearly all European countries, i.e. recorded in accidents in Germany that occurred between 2000 and 2012 can be viewed quite positively on the one hand in that the numbers of wearers are rising, which signals a growing acceptance of helmets on the side of the bicyclists, but the current rate of slightly over 10% is still extremely low.

This current accident study of GIDAS data shows a significant benefit of helmets on the resulting injury frequency and severity of head injuries for bicyclists involved in accidents. In doing so a visible protection against serious head injuries was found: skull fractures, severe brain injuries and skull base fractures alike, all appear to be less common when using a helmet. Virtually no injury reduction resulted for facial fractures (2.6% versus 2.7%) as this is not the region of the head, which is well protected by cycling helmets. Scientific literature also fails to provide evidence of a protective effect in this case. For instance a protective effect was detected for the upper and middle part of the face, but not for the lower facial area, which, due to the small number of cases and a non-significant but trend-wise interpretable statistical test, is also confirmed by this study. A bicycle helmet can be considered particularly effective for older adults. This was particularly evident for the age groups of 50+ years, where a significant increase of severe head injuries occurred in the group of riders without a helmet [27, 28]. Especially for older bicyclists, biomechanics result in higher injury severities of bony and brain structures that can be protected effectively by a helmet. These persons should increasingly protect themselves against head injuries by wearing a helmet, as it is known that the biomechanical load limits for older persons are significantly lower than those of younger ones. Educational campaigns and possibly even legal demands seem to be an appropriate measure to increase helmet wearing rates and thus to reduce the head-injury-severity in this context. It should be mentioned as well that about 40% of cyclists without a helmet, who were involved in traffic accidents resulting in personal injury, suffered head injuries. Injuries outside the protection area of a helmet in the form of facial injuries are relevant only as serious injuries in the form of facial fractures. However, it can be gleaned from the analysis in this study that helmets offer a small benefit as injuries to the upper part of the face are reduced, due to the protruding frontal part of helmet structure. After all, head injuries alone without any other injured body area account for 13% of the most severe injuries in cyclists. In 23% of the cases, the heads of the cyclists were amongst the most severely injured body parts. The main cause of death and moderate disability after bicycle related incidents are head injuries [29].

An optimization of the current models of helmets seems appropriate. For instance, the study showed for the sides and the edges of the helmet, in particular considering shock absorbing aspects, a potential for extending the protection zone currently identified in the existing standard CEN EN 1078. This appears even more important when taking into account that impacts at the side of the helmet seem to result in higher injury severities than impacts at the top. Although the accidents proved a shock absorbing effect for edges at the sides of the helmet, all helmet materials cracked there and resulted in the described injury reduction due to energy absorption. Enlarging the protection zone and optimizing the helmet design in this area, would result in a further optimization by accident related adaptation of the test requirements of CEN EN 1078. The different impact conditions of the head were analyzed regarding the surface of the impact zone. It could be established that 88.3% of all head impacts happened on a flat surface while 11.7% happened on an edgy surface. The majority of the edgy impacts occurred from impacts against edgy parts from cars and trucks.

The increasing impact of traffic safety measures is perceptible, but the continually high numbers of injured bicyclists show that additional measures still need to be implemented. These may be realized via road planning, via vehicle safety through the design of the exterior of the vehicle and active vehicle assistance systems for the prevention of accidents, but also as self-protection measures of the cyclists, for example by wearing suitable protective gear. Injuries of cyclists can be caused by primary or secondary collision with a vehicle or by hitting the road or other obstacles. The heads of riders have been protected by helmets for nearly a century, amongst others in bicycle racing. As early as the beginning of the 20th century, leather crash headgear resembling a crash cap or a crash ring were in use for racing cyclists. It was not until the 70s that development in the helmet sector continued for cyclists on roads. In the mid-70s, the U.S. company Bell started developing helmets made of EPS (Expanded Polystyrene). In cycling teams it quickly turned out that this kind of helmet was able to protect the head much better than previous models, they quickly became the standard in cycling.

In 1970 the Snell Foundation published in the first U.S. standard on bicycle helmets. Only in the late 80s with the introduction of new helmet materials and an emerging impression of usefulness of head protection on the side of the consumer, bicycle helmets started being used in traffic. With the development of international standards for the design of bicycle helmets, the hard shell helmet emerged, which has changed very little to this day, the changes being limited to some design changes and demands on convenience, ventilation and protective effect. The standard CEN EN 1078 [26] applies to Europe. In addition to the technical design and comfort requirements, which are usually described verbally in the standard, there are also technical requirements including shock absorption, retention system and chinstrap fastening as well as durability of the helmet. Shock absorption, the resistance to penetration, effectiveness and strength seem important for the initiation of injuries. In shock absorption tests, the maximum permissible acceleration values for a drop test using a dummy head on a flat slab and a curb are specified for the predetermined protection areas forehead, back of the head, temples and forehead. These conditions should correspond to the impact objects of real accidents. Figure 29 describes the applicable testing zone at the helmet, whose location has been described in the standard and which is determined by the test houses at the helmet, and which is tested by the test houses according to the so-called "worst case" method, the load values having been determined by the test houses themselves.

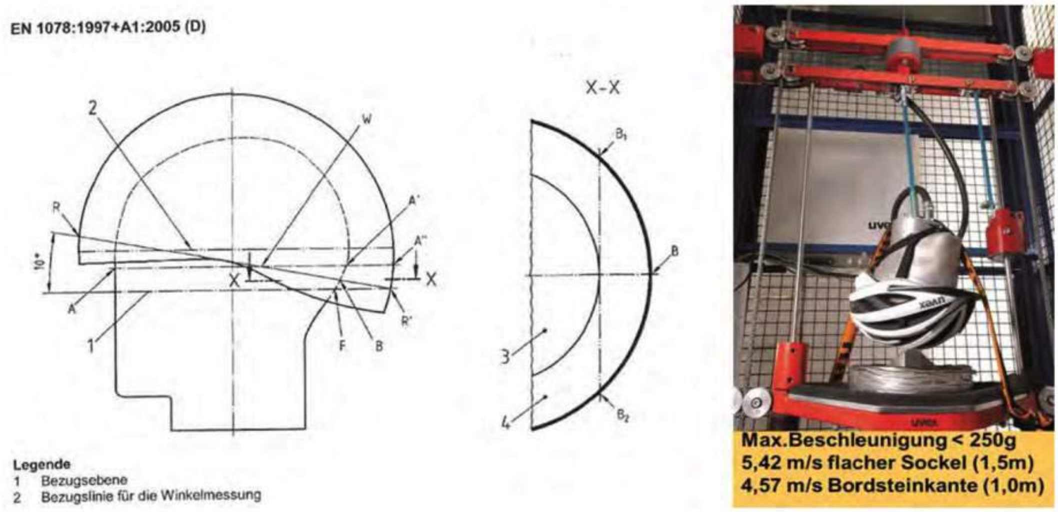



**Figure 29: Shock absorber test in accordance with CEN EN 1078**

However, in view of the established standards, one would have expected a common point of impact there. If this type of damage is correlated in accordance with the protection zone defined in CEN EN 1078, it appears with the current accident study that the lateral edge of the area is not included (Figure 28Figure 28); in future helmet concepts this has to become a requirement for an optimized protective effect. Still, individual cases in the study show that even for a side impact at the helmet, there is almost always a protective effect in the edge part, which usually is not covered by an external hard outer shell over the shock absorption material in those places.

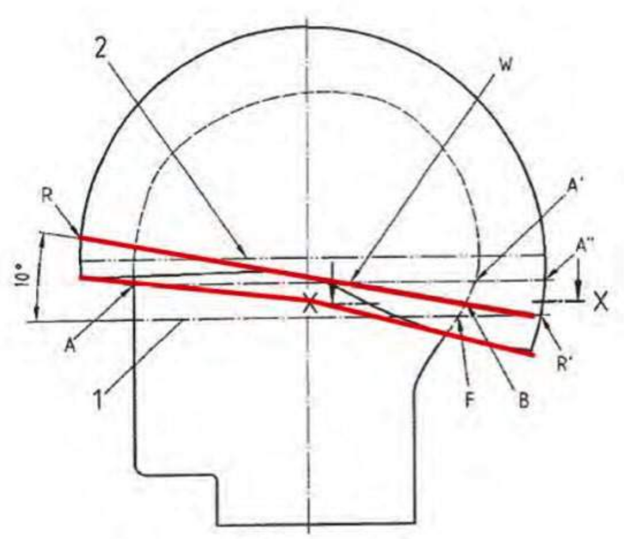



**Figure 30: Modified protection zone based on the results of the study in accordance with CEN EN 1078 [26] taking into account the impact places on the helmet in real-world accidents (R-R´= existing border, A=improved border line).**

The potential of bicycle helmets appears to be not yet fully exhausted. In particular, a helmet may have additional benefits and give opportunity for an implementation of driver assistance systems. A helmet can also contribute to the visibility of cyclists and it can certainly also increase the security awareness of the cyclist and thus help to prevent injuries. However, studies have also revealed that helmets can result in a changed behaviorbehaviour of cyclists, which counterbalance the safety effect of the helmet. In this area additional research is required, to transfer the proven benefits of a bicycle helmet into an effective usage in the real world.

# C. HABITS OF HELMET USAGE OF CYCLISTS BY MEANS OF A REPORTING PROBLEMS IN COMFORT, TEMPERATURE AND CLIMATIZATION REPORTED BY QUESTIONNAIRE REQUESTS

For the COST Action TU1101 a field study was conducted using a questionnaire to investigate the helmet using habits of bicycle riders in different EU-countries.

The questionnaire was developed among the COST partners and resulted in a paper questionnaire including questions from the fields of personal data, helmet data, sensation of the helmet, helmet usage as well as information on a possible former bicycle accident. Due to the fact that some questions of the questionnaire were relevant for different respondents and some were not relevant (e.g. helmet comfort is not relevant for a bicyclist without a helmet), the data collection was conducted by an interview instead of asking the interviewee to fill out the questionnaire by himself.

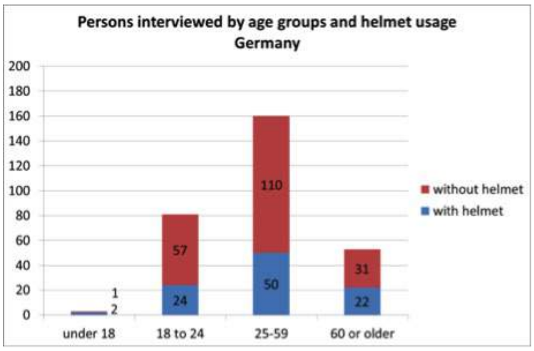
A representative investigation of bicycle riders was not required, however the location and the time of interviewing riders was distributed to different locations and times. In Germany interviews were conducted at colleges/universities which lead to a significant portion of younger bicyclists and interviews were also conducted at supermarket during normal work hours which lead to a higher portion of elderly bicyclists. Due to the lack of representativeness this study is not suitable to evaluate helmet wearing rates.

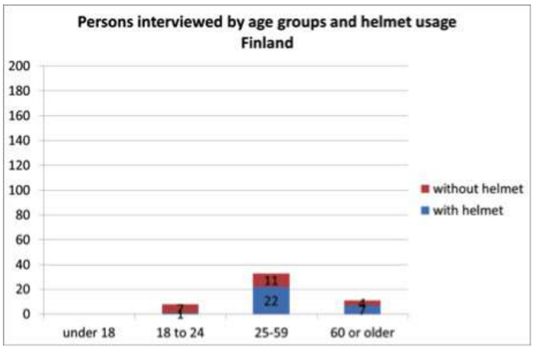
In Table 7 an overview over the available data from the interviews is given. In total 994 riders were interviewed in Germany, Finland, Greece, Italy and Portugal. Of these riders 356 had been wearing a helmet and could respond to the questions about the helmet and 237 riders had had a bicycle accident before. Among these riders were 647 men and 347 women. It has to be noted that the statistical significance of the analysis is not always given due to low case numbers in the different countries.

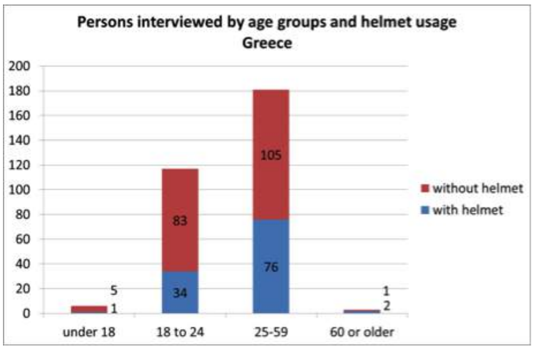
| Country | Germany | Finland | Greece | Italy | Portugal | Total |
|---|---|---|---|---|---|---|
| Total number of riders interviewed | 297 | 52 | 307 | 148 | 190 | 994 |
| Riders with a helmet | 98 | 30 | 113 | 29 | 86 | 356 |
| Riders that had a bicycle accident before | 65 | 4 | 89 | 40 | 39 | 237 |

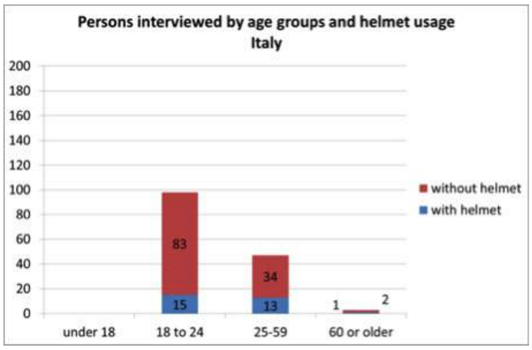
**Table 7: Overview of riders interviewed by participating country**

The data shows that there is no substantial difference in helmet wearing behaviour between men and women in general when looking at the relation between the collected numbers of helmet wearers and non-wearers. Figure 31 displays the portion of helmet users for different age groups among the interviewed cyclists in the 5 participating countries. The two age groups which allow a descriptive analysis due to sufficient case numbers are young riders aged 18 to 24 and more experienced riders aged 25 to 59. The majority of riders were from the latter group with the exception of Italy, where the majority of riders were aged 18 to 24. For all countries however a slightly higher wearing rate of bicycle helmets could be observed among riders aged 25 to 59 in comparison to the younger riders.



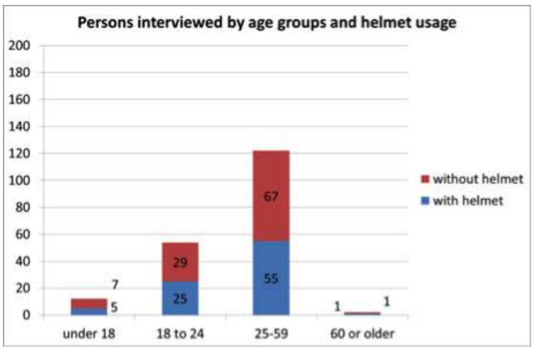
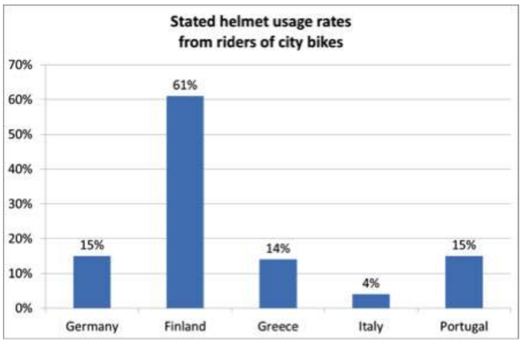
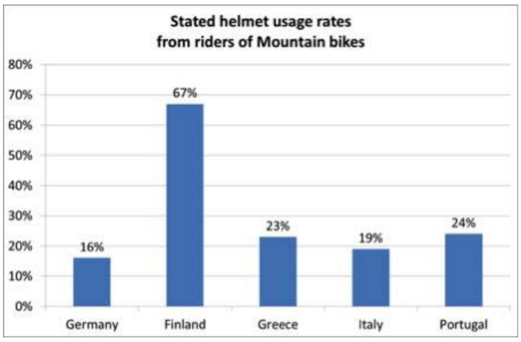




**Figure 31: Portion of helmet users for different age groups among the interviewed cyclists in the 5 participating countries**

The interviewed riders mostly used city bikes (66% in Germany, 71% in Finland, 48% in Greece, 46% in Italy and 35% in Portugal) followed by mountain bikes (13% in Germany, 6% in Finland, 22% in Greece, 40% in Italy and 33% in Portugal) and racing bikes (10% in Germany, 8% in Finland, 17% in Greece, 10% in Italy and 8% in Portugal).

The portion of city bike riders that stated that they always use helmets was rather low for Germany, Greece, Italy and Portugal with under 16% (see Figure 32). In Finland however over 60% of the city bike riders stated that they always wear a helmet. A very similar distribution is found among the riders of mountain bikes where again Finland has much higher shares of stated helmet usage. Riders of racing bikes however seem to use helmets more often. In Portugal 19% stated that they always use a helmet and in the other countries the rate of stated helmet usage was even over 30%.



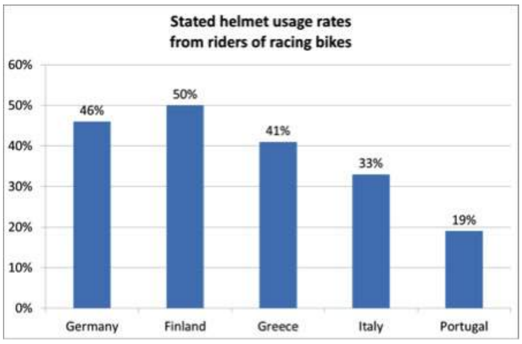




**Figure 32: Percentage of cyclists which stated that they always use helmets from the participating countries for the most common types of bicycles**

Furthermore the safety sensation when riding the bicycle was questioned: the riders were asked if they felt that cycling was much safer, a little safer, about the same, a little more dangerous or much more dangerous compared to driving a car and compared to walking. The results for the 5 participating countries are depicted in the Annex A.1.1 – A.1.5. Bicycle riders in all countries showed a similar characteristic of safety feeling.


**Figure 33: Safety sensation of cyclists in all participating countries compared to other types of traffic participation, analysed separately for cyclists wearing a helmet and not wearing a helmet**

Figure 33 shows a combined analysis for all five countries participating in this COST quest. Cycling was felt to be more dangerous for most of the respondents. Compared to driving a car cycling was felt to be a little more dangerous for 36% of those that had used a helmet and 45% for those that had not used a helmet and 25% respectively 20% even thought that cycling was much more dangerous than driving a car. The safety sensation of cycling compared to walking was very similar of that compared to driving a car. However here less riders thought that it was much safer (2%-3%) or a little safer (5%-7%) while 27% though that compared to walking cycling is equally dangerous or safe.

The difference of the safety sensation between the groups of helmet users and non-users seems not to be significant.

To identify the reasons of riders for using a helmet or respectively for not using a helmet, a list of possible reasons was given and the interviewed people were asked to rate the relevance of each of these reasons with: 0 - never a reason; 1 – rarely a reason; 2 – often a reason; 3 – mostly a reason; 4 – always a reason. The figures in the Annex A.2.1 – A.2.5 show the mean values of the ratings of these reasons for using a helmet and for not using a helmet for the 5 participating countries. When looking at the reasons for wearing a helmet the reasons "It's only a short distance"; "High temperatures"; "Carelessness", "All this take on, take off, waists my time" and a poor risk assessment had the highest mean scores with most of the 5 countries. While "overconfidence" or a the interference with social image were rarely given as a reason for not wearing a helmet. Interestingly the helmet being too expensive also had low scores for being a reason not to wear a helmet in Germany (mean value = 0.73) and in Finland (mean value = 0.33). In Greece, Italy and Portugal however the price of a helmet plays a greater role with mean values between 1.2 and 2.08.

One reason for not wearing a helmet which was often mentioned in Germany but which was not anticipated and thus was not available on the list of reasons was: "when I reach my destination I have to carry around my helmet".

On the other hand the reasons for wearing a helmet are mostly the feeling of safety in all countries except for Portugal. In Germany and in Finland "being used to wear a helmet" also have high scores for reasons to wear a helmet. In Greece and Italy "bumpy roads" and "long distances" are also among the highest rated reasons for wearing a helmet together with the feeling that the other traffic participants "drive like crazy" in Italy. In Portugal interestingly the feeling of safety seems not to be among the highest rated reasons for wearing a helmet (mean = 1.69), while the lack of cycling experience, narrow roads and previous crashes had the highest scores.

The information on the sensation of using a bicycle helmet and whether there are any constraints when using the helmet was also collected with the questionnaire for those riders that had used a helmet. Asked about hearing problems when wearing a helmet (Table 8) the riders rarely stated that this was the case in most countries. An exception here was Portugal, where 34% of the riders with helmets stated that they do have hearing problems when wearing a helmet.

| Do you have hearing problems when using the helmet? | | | |
|---|---|---|---|
| Germany | No: 99% | Yes: 1% | (n=96) |
| Finland | No: 100% | Yes: 0% | (n=29) |
| Greece | No: 95% | Yes: 5% | (n=111) |
| Italy | No: 100% | Yes: 0% | (n=28) |
| Portugal | No: 66% | Yes: 34% | (n=86) |

**Table 8: reported hearing problems of cyclist due to use of a helmet.**

Additionally the riders were asked if they feel that the helmet narrows their field of vision when riding (Table 9). Here also the majority stated that the helmet does not limit the vision. However some riders, especially in Portugal, do think that this is the case.

| Does the helmet narrow your field of vision? | | | |
|---|---|---|---|
| Germany | No: 93% | Yes: 7% | (n=95) |
| Finland | No: 100% | Yes: 0% | (n=29) |
| Greece | No: 95% | Yes: 5% | (n=112) |
| Italy | No: 96% | Yes: 4% | (n=28) |
| Portugal | No: 71% | Yes: 29% | (n=86) |

**Table 9: Reported sensation of cyclists if the helmet narrows their field of vision.**

The reported sensation of the riders if the they feel that the helmet use makes them sweat more when riding the bicycle has a tendency to be the case with over 60% in Finland, Italy and Portugal. In Germany (40%) and in Greece (43%) less than half of the interviewed riders feel that they sweat more when riding a bike. In any case a relationship between the helmet use and the feeling of sweating more can be seen.

| Does the helmet make you sweat? | | | |
|---|---|---|---|
| Germany | No: 60% | Yes: 40% | (n=91) |
| Finland | No: 39% | Yes: 61% | (n=28) |
| Greece | No: 57% | Yes: 43% | (n=111) |
| Italy | No: 36% | Yes: 64% | (n=28) |
| Portugal | No: 31% | Yes: 69% | (n=86) |

**Table 10: Reported sensation of cyclists if the helmet makes them sweat when riding the bike.**

Asked about headaches or other unpleasant symptoms after using a bicycle helmet, a minority (between 4% and 7%) of the riders said that they do sometimes feel unpleasant symptoms (Table 11). The riders stated that they sometimes have a headache, one rider felt a pressure and markings on the skin of the forehead and also in one case one rider responded that she gets a dry and itchy skin on the head from using a helmet.

| After helmet use, do you have headaches or other unpleasant symptoms? | | | |
|---|---|---|---|
| Germany | No: 93% | Yes: 7% | (n=95) |
| Finland | No: 93% | Yes: 7% | (n=30) |
| Greece | No: 94% | Yes: 6% | (n=107) |
| Italy | No: 96% | Yes: 4% | (n=27) |
| Portugal | No: 92% | Yes: 8% | (n=86) |

**Table 11: Reports of cyclists if the helmet causes unpleasant symptoms like headaches.**

The interviewed riders were ultimately asked about previous bicycle accidents. 205 cyclists from all countries indicated the type of accident they had had (see Figure 34). With 49% nearly half of the riders stated that they had a single-vehicle accident (e.g. a fall due to a driving error). The second most frequent collision partner were cars with 28%. The remaining types of collision partner were rather seldomly reported with less than 10% each.

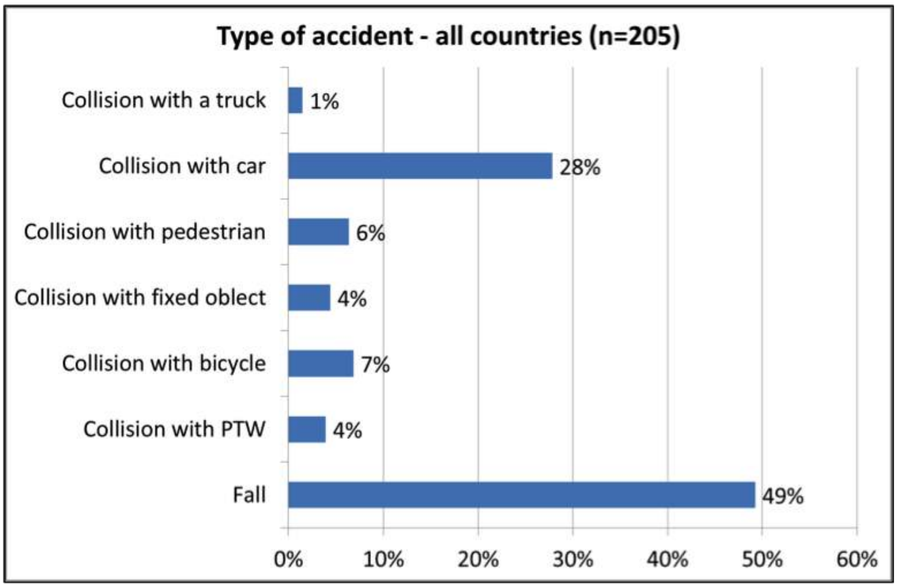



**Figure 34: Reported type of accident of cyclists that stated that they had been in a bicycle-accident before**

If the respondents had been wearing a helmet at the time of the accident and if the helmet had an impact during the accident, they were additionally asked where the main impact zone on the helmet was. As displayed in Figure 35, of the 82 riders with a helmet impact, the majority had an impact to the side of the helmet (29 impacts on the left side and 23 impacts on the right side). The second most frequent impact location was stated to be the front of the helmet (20 impacts). Impacts on the top of the helmet (n=6) and at the back of the helmet (n=4) were rarely reported.

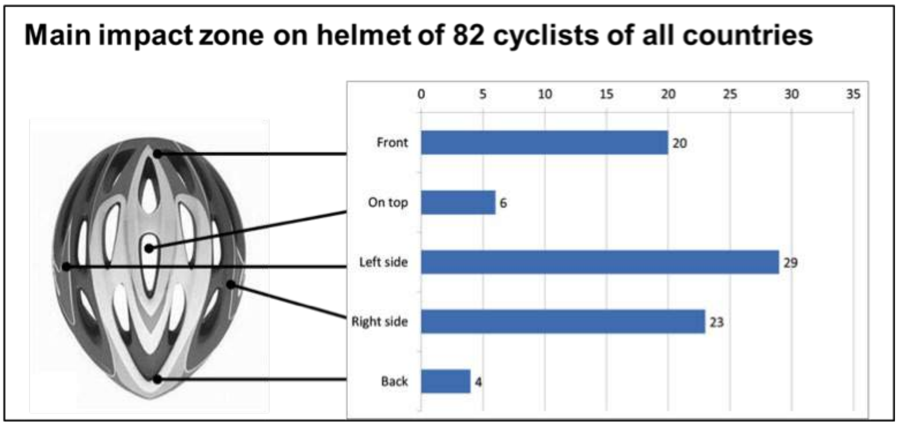



Figure 35: Reported main impact zone on helmet of cyclists that had a helmet impact in the scope of an accident.

# CONCLUSION

The 994 answered questionnaires which were available for the analysis are not representative for the cycling situation of the participating countries because different countries had different times and locations of questioning and thus the interviewed riders could not be randomly picked at random places. However the study revealed that the helmet wearing rates seem to depend on the type of bicycle used. As such riders of racing bikes seem to use helmets more often than riders of other types of bicycles, which could be seen for most COST WG1 partner countries.

The combined analysis for all five countries participating in this COST quest revealed that in general bicycle riders thought that riding a bicycle is more dangerous than driving a car or walking with no major differences between responding riders with or without a helmet. The most common reasons for not wearing a helmet were riding a short distance; high temperatures; Carelessness, "All this take on, take off, waists my time" and a poor risk assessment, while the most common reason for wearing a helmet was the feeling of safety with a helmet in most countries. So the riders are aware of the risk of riding a bicycle and believe that the helmet does have a potential for protection but carelessness and a missing solution where to leave the helmet at the destination often leads to not wearing a helmet.

Furthermore the questionnaire revealed that the helmet usage rarely leads to hearing problems or problems concerning the vision such as a narrowed field of vision. However some riders complained about unpleasant symptoms after using the helmet such as headaches. The fact that using the helmet makes you sweat more was also stated often as an unpleasant symptom.

Asked about previous bicycle accidents, those riders that had been in an accident before reported that it had mostly been a single vehicle accident where they fell off the bicycle for different reasons. Less than 1/3rd were collisions with cars. Collisions with other traffic participants or with objects were rarely reported. Here the main impact zones of the helmet were stated to be the sides of the helmet and the front. Hence according to this analysis the main function of protection of the helmet should be to protect against injuries at the side of the head or at the face when hitting the ground.

# D. IDENTIFICATION OF INFLUENCES FOR SAFETY ASPECTS OF THE SEATING GEOMETRY AND THE POSTURE OF CYCLISTS AND THE HELMET POSTION WHEN RIDING A BICYCLE

## INFLUENCE OF THE BICYCLE HELMET USAGE ON THE POSTURE OF CYCLISTS

Within the COST Action TU1101 working group 1 conducted also study to identify the influence of the seating posture of a cyclist for using the helmet in right position on the head. This study was conducted in Germany, Finland, Greece, Turkey and Portugal by taking pictures of cyclists and comparing the seating geometry of riders with a helmet and riders without a helmet.

The number photos of cyclists that were taken from the participating countries and where it was possible to measure the geometric values are displayed in Table 12.

In total 1565 pictures were analysed in 5 different countries of Europe with the majority being cyclists without a helmet n= 1231 non helmet drivers compared to n=334 cases with helmet which were riding on city bikes (n=1027). Further common types were Mountain bikes (n=410), Racing bikes (n=66). Other types of bicycles like folding bikes, transport bikes or hybrid bikes which could not clearly be assigned to another group were photographed in 62 cases.

| | Germany | | Finland | | Greece | | Turkey | | Portugal | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pictures | 1150 | | 107 | | 157 | | 7 | | 144 | | 1565 | |
| | w/o helmet 980 | With helmet 170 | w/o helmet 0 | With helmet 107 | w/o helmet 154 | With helmet 3 | w/o helmet 3 | With helmet 4 | w/o helmet 94 | With helmet 50 | w/o helmet 1231 | With helmet 334 |
| City bike | 907 | | 54 | | 37 | | 2 | | 27 | | 1027 | |
| Mountain bk. | 172 | | 33 | | 111 | | 4 | | 90 | | 410 | |
| Racing bike | 40 | | 18 | | 3 | | 1 | | 4 | | 66 | |
| Other | 31 | | 2 | | 6 | | 0 | | 23 | | 62 | |

**Table 12: Number of cyclist photos provided by the participating partners.**

Bicycle riders which did and did not use a cycle helmet were photographed while riding the bicycle in a real world (non fictional) situation. The picture was taken anonymously from a large distance using a telephoto lens without the perception of the bicyclist. To be able to measure the seating posture correctly it is necessary to take pictures of cyclists riding rectangular to the photo axis (taking a picture exactly from the side of the cyclist).

To define the seating geometry the sitting decline SD (angle of the cyclist's torso) and the angle between the handlebar and the seat HS were established for both riders with and without helmets (see Figure 36). Also the head posture HP was measured by the inclination of the line from the ear to the eye (see Figure 37). Subsequently the inclination of the line of the visual limit VL upwards due to the front of the helmet or its sun shade was investigated from pictures of riders that had used a helmet.


**Figure 36: Establishment of angels relevant for seating geometry and vision limits**


**Figure 37: Establishment of the head posture angle by measuring the inclination of the line from the ear to the eye.**

As the pictures taken could be askew a horizontal reference line was established in a first step which was used as a base line to measure the angles (see red line in Figure 36). A possible reference for this purpose is the line between the two axles of the bicycle, but could also be a horizontal line of building if e.g. the axles of the bicycle wheels are not visible on the photo.

The case collective is dominated by the pictures from Germany (1150 of 1565 pictures). Here the pictures were mostly taken during normal working hours at a "bicycle highway" which represents a major bicycle path separated from other traffic and which connects an urban district with the city centre. The share of helmet wearers cannot be called representative because the focus of this study was set to collecting as many cyclists with a helmet as possible.

The analysis of the cycle geometry shows that about the same amount more pictures of male riders with a helmet were taken like of female riders with a helmet (144 men; 140 women) and that in the group of riders without a helmet the amount of male riders (643) was higher than the amount of female riders (494). It has to be noted that the gender and the age group of the rider was estimated from the pictures.

| Age group | Germany (n=1149) | Finland (n=107) | Greece (n=157) | Turkey (n=7) | Portugal (n=144) |
|---|---|---|---|---|---|
| Younger than 18 | 36% (4 from 11) | 100% (5 from 5) | 0% (0 from 16) | n.a. | 44% (4 from 9) |
| 18-40 years | 16% (84 from 527) | 100% (71 from 71) | 2% (2 from 82) | 57% (4 from 7) | 33% (36 from 109) |
| 41-65 years | 11% (55 from 492) | 100% (31 from 31) | 2% (1 from 54) | n.a. | 38% (10 from 26) |
| 66 or older | 23% (27 from 119) | n.a. | 0% (0 from 2) | n.a. | n.a. |

**Table 13: Share of helmet users among the photographed riders for different age groups in the participating countries. Number of riders with helmet and total number of riders are included in brackets.**

The share of the riders that had used a helmet for the age groups is shown in Table 13 in the participating countries in this task. In Germany the share of riders with a helmet lies between 11% for those aged 41-65 years and 36% for those younger than 18 years. Older riders (66+) also had a slightly higher incidence of helmet usage with over 20% than those aged between 18 and 65 years. In Finland only riders that had used a helmet were photographed, while in Greece only 2% of the riders aged 18-40 and aged 41-65 wore a helmet. The 7 pictures from Turkey are all of riders aged between 18 and 40 years, and 4 had been wearing a helmet when the picture was taken. In Portugal a rather high share of riders with a helmet were photographed. For all age groups where pictures of riders were available the share of helmet users lies above 33%.

For the following analysis the combined sample of pictures of all countries was used because it is assumed that differences in postures are rather prone to different bicycle types than to the nationalities.

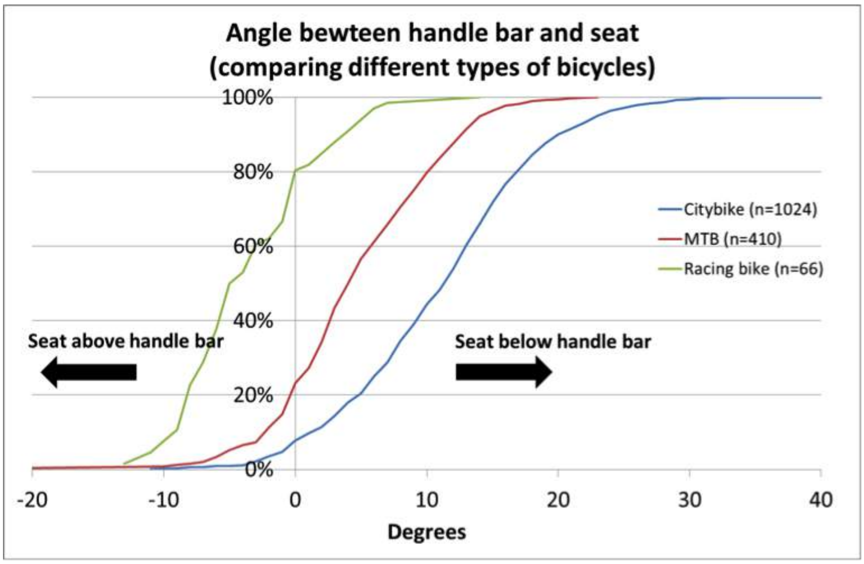



Figure 38: Angle between handle bar and seat for different types of bicycles

The angle between the handlebar and the seat of the bicycle is a geometrical measure of the bike and influences the sitting posture. The cumulative frequency of this measure is shown in Figure 38 for the 3 most common types of bicycles. About 80% of the photographed racing bikes have their handle bar on a lower level than the seat, 20% even have a clearly higher seat than handle bar (angle HS of nearly -10°). This angle has a clear shift towards higher handle bars for mountain bikes. About 80% have a handle bar on a higher level than the seat. City bikes have an even higher tendency towards higher handle bars and lower seats: In over 90% the handle bar was above the level of the seat and in just about 60% of the pictures of city bikes the angle between handle bar and seat was 10° or more.

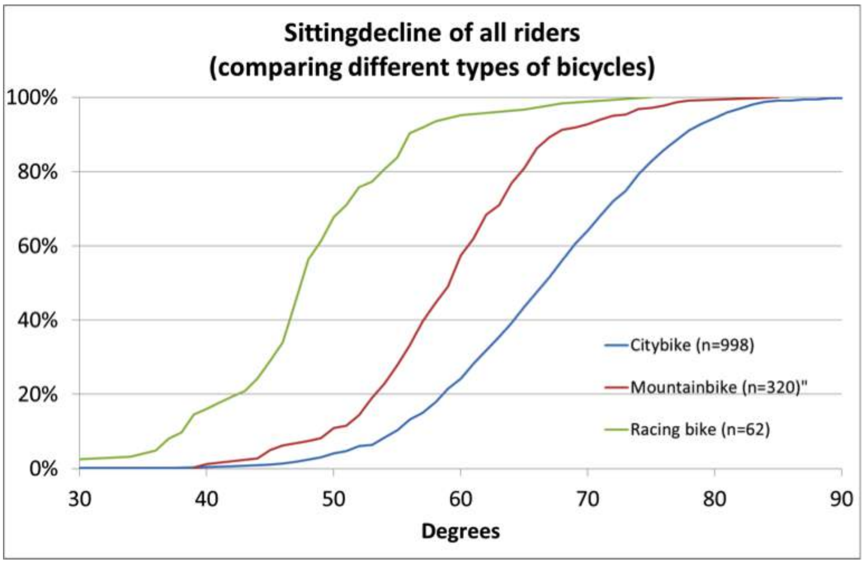



Figure 39: Sitting decline - angle of the cyclist's torso for different types of bicycles

As expected the geometrical measure of the angle between the handlebar and the seat has a clear influence on the sitting decline (the angle of the riders torso) which is displayed in Figure 39. About half of the riders of city bikes have a sitting decline of over 67° and thus have a more upright torso than riders of mountain bikes where half of the riders have a sitting decline of under 58° or than riders of racing bikes, where half of the riders have a sitting decline of 45° or even less.

## ANALYSIS OF INFLUENCE OF HELMET USE ON THE HEAD POSTURE BASED ON RIDERS OF CITYBIKES

To analyse the influence of the helmet use on the head posture only city bikes (the largest groups of bicycle types) were used to exclude the influence of the posture difference by the bicycle type.

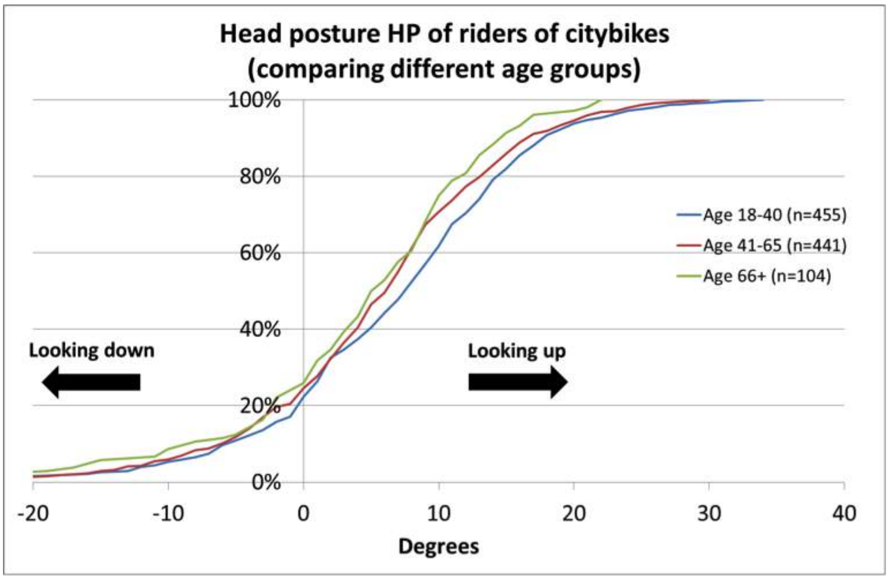



**Figure 40: Head posture (inclination of the line from the ear to the eye) of riders of city bikes, comparing different age groups.**

The cumulative frequency of the Head posture (inclination of the line between the ear and the eye) for riders of city bikes only is displayed in Figure 40 for different age groups. It is interesting to see, that the age does not seem to have a large influence on the head posture of the riders.

About half of the photographed riders of city bikes had an angle between the ear and the eye of less than 10°. In general it is presumed that the influences from the momentary head movements and the individual differences between of the angle between ear and eye of the people are compensated by the high number of evaluated photos.

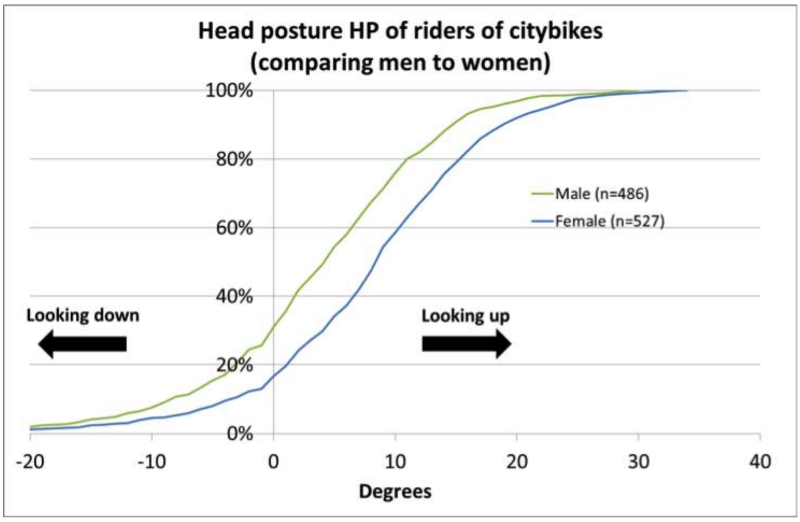



**Figure 41: Head posture (inclination of the line from the ear to the eye) of riders of city bikes, comparing male to female riders.**

In contrast to the age, the gender of the cyclist does seem to have a slight influence on the head posture (see Figure 41). While half of the men have an inclination of the line between the ear and the eye which is lower than 4° that of the women is about 5° higher in average (50% of women have a head posture of 9° or higher). A possible explanation for this variation could be the slightly different posture of the back: While male city bike riders have an average sitting decline of over 65°, the sitting decline of women was 68° in average.

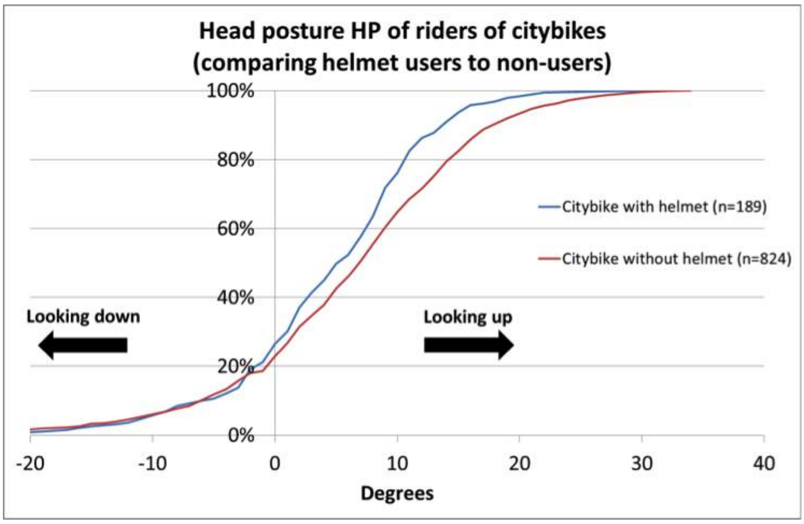



**Figure 42: Head posture (inclination of the line from the ear to the eye) of riders of city bikes, comparing helmet users with non users.**

For the comparison of the head posture of riders with and without a helmet all age groups were taken due to the minor influence from the age of the riders. Figure 42 shows the cumulative frequency of the head posture for city bike rides with a helmet and without a helmet. The helmet usage seems to have an influence especially on riders that have their head in a higher position. Here the riders with a helmet seem to lower their heads more than those without helmets: While 80% of the helmet users have a head posture of less than 10°, some 20% of the riders without a helmet have head postures of 14° or more.

In a further step the vertical vision limit VL due to the helmet was established for the city bike riders with helmets by constructing a line from the eye to the front rim of the helmet (usually the sun shade) at the moment when the picture was taken. The cumulative frequency of this angle for riders with a helmet of different age groups is shown in Figure 43.

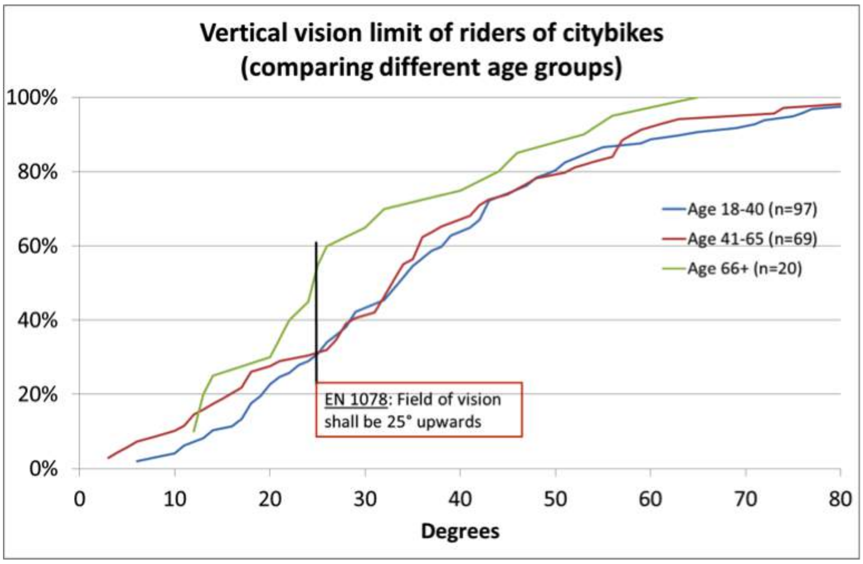



**Figure 43: Vertical vision limit (vision limit upwards due to the helmet) of riders with helmets of city bikes, comparing different age groups**

Interestingly younger riders (18-65 years) have found to have a higher vision angle upwards than older riders aged 66 years or older: While half of the younger riders have a vision limit upwards of nearly 35 degrees, half of the older riders are just over 25 degrees and thus are at the limit of the upwards field of vision for cyclists with bicycle helmets when looking straight forward, as described in EN 1078. So if the younger riders have a higher vision angle upwards than the older riders and at the same time the head posture (looking upwards or downwards) is approximately the same for both age groups it can be assumed that older riders wear their helmets more turned forward into the face or have more helmets with a pronounced sun shade.

**Limitation of this study:**

People constantly move their heads when riding a bicycle. The pictures taken of these cyclists can only give a momentary position of the head. Due to the number of pictures taken and analysed these effects are compensated only to a certain degree. Further it is possible to identify on the pictures wether the helmet is used correctly. However the correct use of the chin strap cannot be identified on the pictures. Additionally the location of the photo (incline or decline) may have in influence on the seating position of the cyclist. This fact was not taken into account. However the vast majority of the analysed pictures were from the city of Hannover where no relevant slope of the cycle path is present.

# CONCLUSION ON SEATING POSITION AND INFLUENCES TO HELMET USE

For the second COST WG1 field study the methodology of taking pictures from bicycle riders to evaluate the seating posture has proven to be a viable technique to identify general angles describing the seating positions, even though it is not possible to identify the exact angles in every case. Together with the estimation of the age group to which the rider belongs it was possible to analyse the seating position depending on the helmet usage and the different age groups. A total of 1565 pictures of riders were taken from the participating partners where two thirds of cyclists were riding city bikes.

The incline of the line between the handle bar and the seat describes if and how much the handle bar is above the seat. Here riders using a city bike had in average adjusted the handle bar higher above the seat than riders of mountain bikes and especially than riders of racing bikes which had the lowest incline between the handle bar and the seat. The posture of the upper body (sitting decline) correlated pretty much with the incline of the line between the handle bar and the seat and was highest for the riders of city bikes (the majority on the group of cyclists) with a sitting decline of over 67° for half of the riders. For the analysis of the influence of helmet use on the head posture (inclination of the line from the ear to the eye) only the largest group of riders (city bikes) was analysed. Here the age did not seem to have substantial influence on the head posture of the riders. However male riders do look down a bit more than female riders (5° on average). The helmet usage also seems to have an influence on the head posture: Especially riders that have their head in a higher position seem to lower their head more when using a helmet than those without helmets: While 80% of the helmet users have a head posture of less than 10°, some 20% of the riders without a helmet have head postures of 14° or more. The vertical vision limit, which describes the vision limit upwards due to the helmet front (e.g. sun shade) was found to be influenced by the riders age. Older riders seem to wear their helmets more turned forward into the face or have more helmets with a pronounced sun shade: While half of the younger riders have a vision limit upwards of nearly 35 degrees, half of the older riders are just over 25 degrees.

# SUMMARY

The COST Action operates under the acronym “HOPE” (Helmet OPtimization in Europe) with the goals to:

- *Increase scientific knowledge about bicycle helmets in regards to traffic safety.*
- *To disseminate this knowledge to stakeholders, including cyclists, legislators, manufacturers, and the scientific community.*
- *To stimulate international collaboration in de field of bicycle traffic safety and helmets.*

There are 4 working groups, which have to disseminate their results within a summery report. Working group WG1 carried out accident analysis and carried out field studies to follow their tasks for optimazing the bicycle helmet:

1. Development of an Pan European Database on In-depth accident results on Injury Statistics
2. Development of acceptance criteria and finding problems in bicycle helmet use.

As partners of this network within WG 1 the Univerities Hannover (Germany), Pavia (Italy), Heraklion and Athens (Greece), Lisbon (Portugal) as well as the Finnish Motor Insures Centre Helsinki and AGU Zürich (Switzerland) worked together in one working group (WG 1) dealing with 3 different topics:

# A. Report on injury situation of bicyclists in traffic accidents on a European level with focus on helmet usage

# B. In-depth Accident analysis of head injuries and the effectiveness of the bicycle helmet in Real Accident Situations

# C. Habits of helmet usage of cyclists by means of a reporting problems in comfort, temperature and climatization reported by questionnaire requests

# D. Identifying the influences of the seating geometry, the posture and the helmet postion of cyclists on safety aspects

The statistical data on bicycle accidents in Europe was analysed by using the bicycle basic-fact-sheets based on CARE data and by using data provided be the participants of WG1. It can be seen that the cyclist fatalities were decreasing between the years 2001 and 2010 in Europe. However there is a difference between the European countries, as such the fatality (fatalities per million inhabitants) varies from 1 (Ireland) to over 8 fatalities per million inhabitants in Netherlands, Romania and Hungary. Furthermore in Denmark for example over 75% of cyclist fatalities occurred in urban areas, while only 26% occurred in urban areas in Spain. Based on the national statistical data provided by the COST partners the injury situation of was compared and again revealed major differences between the countries concerning the share of injured bicyclists of all injured traffic participants. It has to noted that comparability here is difficult due to different definitions concerning slight and severe injuries among the different countries. The reported helmet using rate in the different European countries varies from 3% in Italy to over 50% in Norway, if looking to all age groups of bicyclists. The highest rate can be seen for children, as in some countries like

Austria or Sweden a mendatory use of the helmet is established for children. According to the EU Injury Database IDB 32% of road accident casualties recorded in the database were admitted to the hospital overall, while this was the case only for 23% for cyclists. Cyclists especially suffered from fractures and open wounds more frequently than other road users. An overview over the bicycle helmet legislation in different countries worldwide shows that for many countries no information was available which often means that no helmet wearing requirements are in place. In some countries there is a mandatory helmet use for certain age groups (mostly children). Some countries however state that there is no intention of introducing a mandatory helmet law, based partly on international views that a mandatory requirement may lead to a reduction in cycling activities.

A study conducted on bicycling and alcohol use and aspects of helmet use with German in-depth data [5] revealed that riding under the influence of alcohol does have an influence on the proportion of guilt for causing the accident but also on the helmet usage rates. Cyclists which did not wear a helmet were more likely to have consumed alcohol. Furthermore cyclists who were not responsible for the collision were less likely to have consumed alcohol than those who were partially responsible for the accident. Cyclists involved in collisions with another vehicle, motorised or not, had a lower risk of suffering a head injury compared with those involved in single vehicle accidents.

Accident investigation of e-bikers in Switzerland showed that most e-bikers who were involved in an accident were older than most accident-involved bicyclists and the analysis of the type of accident revealed e-bikers to be involved in single accidents most frequently [30]. In Switzerland 52% of the accident-involved e-bikers wore helmets while bicyclists wore helmets less frequently. It was also concluded that bicyclists and e-bikers aged 40+ are at higher risk of sustaining severe injuries than bicyclists and e-bikers aged 0-39

An accident analysis of head injuries using the database of the German in-depth Accident Study (GIDAS) revealed that wearing rate of bicycle helmets recorded in the accidents which occurred between 2000 and 2012 can be viewed quite positively on the one hand in that the numbers of wearers are rising in Germany, which signals a growing acceptance of helmets on the side of the bicyclists, but the current rate of slightly over 10% is still extremely low.

Furthermore the study of GIDAS data shows a significant benefit of helmets on the resulting injury frequency and severity of head injuries for bicyclists involved in accidents. In doing so a visible protection against serious head injuries was found: skull fractures, severe brain injuries and skull base fractures alike, all appear to be less common when using a helmet. Virtually no injury reduction resulted for facial fractures (2.6% versus 2.7%) as this is not the region of the head, which is well protected by cycling helmets. Scientific literature also fails to provide evidence of a protective effect in this case. For instance a protective effect was detected for the upper and middle part of the face, but not for the lower facial area, which, due to the small number of cases and a non-significant but trend-wise interpretable statistical test, is also confirmed by this study. A bicycle helmet can be considered particularly effective for older adults. This was particularly evident for the age groups of 50+ years, where a significant increase of severe head injuries occurred in the group of riders without a helmet. Especially for older bicyclists, biomechanics result in higher injury severities of bony and brain structures that can be protected effectively by a helmet. These persons should increasingly protect themselves against head injuries by wearing a helmet, as it is known that the biomechanical load limits for older persons are significantly lower than those of younger ones. Educational campaigns and possibly even legal demands seem to be an appropriate measure to increase helmet wearing rates and thus to reduce the head-injury-severity in this context. It should be mentioned as well that about 40% of cyclists without a helmet, who were involved in traffic accidents resulting in personal injury, suffered head injuries. Injuries outside the protection area of a helmet in the form of facial injuries are relevant only as serious injuries in the form of facial fractures. However, it can be gleaned from the analysis in this study that helmets offer a small benefit as injuries to the upper part of the face are reduced, due to the protruding frontal part of helmet structure. After all, head injuries alone without any other injured body area account for 13% of the most severe injuries in cyclists. In 23% of the cases, the heads of the cyclists were amongst the most severely injured body parts. An optimization of the current models of helmets seems appropriate. For instance, the study showed for the sides and the edges of the helmet, in particular considering shock absorbing aspects, a potential for extending the protection zone currently identified in the existing standard CEN EN 1078. This appears even more important when taking into account that impacts at the side of the helmet seem to result in higher injury severities than impacts at the top. Although the accidents proved a shock absorbing effect for edges at the sides of the helmet, all helmet materials cracked there and resulted in the described injury reduction due to energy absorption. Enlarging the protection zone and optimizing the helmet design in this area, would result in a further optimization by accident related adaptation of the test requirements of CEN EN 1078. The different impact conditions of the head were analyzed regarding the surface of the impact zone. It could be established that 88.3% of all head impacts happened on a flat surface while 11.7% happened on an edgy surface. The majority of the edgy impacts occurred from impacts against edgy parts from cars and trucks.

To analyze the helmet usage practice of bicyclists in Europe Working group 1 developed a questionnaire to collect relevant information by means of a field study carried out in the years 2010 to 2014. It might be regarded as a limitation that the 994 answered questionnaires which were available for the analysis of the helmet usage are not representative for the cycling situation in Europe because the interviewed riders could not be randomly picked at random places during random times and interviews were only conducted in 5 different countries. However the study revealed that the helmet wearing rates seem to depend on the country and the type of bicycle used. As such riders of racing bikes seem to use helmets more often than riders of other types of bicycles and in Finland generally more cyclists use helmets than in the other participating countries. In general bicycle riders with or without a helmet thought that riding a bicycle is more dangerous than driving a car or walking. The reason for not wearing a helmet was mostly just carelessness, short distance, high temperatures or the need to carry around a helmet at the destination, while the most common reason for wearing a helmet was the feeling of safety. So the riders are aware of the risk of riding a bicycle and believe that the helmet does have a potential for protection but carelessness and a missing solution where to leave the helmet at the destination often leads to not wearing a helmet. Furthermore the questionnaire revealed that the helmet usage rarely leads to hearing problems or problems concerning the vision such as a narrowed field of vision in most countries. However some riders complained about unpleasant symptoms after using the helmet such as headaches. The fact that using the helmet makes you sweat more was also stated often as an unpleasant symptom. Asked about previous bicycle accidents, those riders that had been in an accident before reported that it had mostly been a single vehicle accident (48%) where they fell off the bicycle for different reasons or a collision with a car (26%). Collisions with other traffic participants or with objects were rarely reported. Here the main impact zones of the helmet were stated to be the sides of the helmet and the front. Hence according to this analysis the main function of the helmet should be the protection against injuries at the side of the head and at the face when hitting the ground.

In the scope of a second field study the methodology of taking pictures of bicyclists to evaluate the seating posture was developed by Working Group 1. It has proven to be a viable technique to identify general angles describing the seating positions, even though it is not possible to identify the exact angles in every case. Together with the estimation of the age group to which the rider belongs it was possible to analyse the seating position with respect to the helmet usage and the different age groups. The incline of the line between the handle bar and the seat describes if and how much the handle bar is above the seat. This measure is significantly influenced by the type of bicycle: While racing bikes often have a handle bar which is below the level of the seat, this is not the case in mountain bikes or city bikes. The posture of the upper body (sitting decline) is influenced by the type of bicycle as well and therefore the analysis of the head posture was conducted only for city bikes (the most common group of bicycles in the sample). In general the analysis of the photos revealed that the age of the rider has no significant influence on the head posture. Interestingly the helmet usage seem to have an influence on the head posture: Riders with a helmet held their head slightly lower than riders without a helmet. The vertical vision limit due to the helmet is determined by the front rim of the helmet (mostly the sun shade). Typical values here range from just above 0° (horizontal line from the eye to the sun shade) to 75° upwards. Here the elderly riders tend to have a slightly enhanced limit of vision upwards, meaning a lower vision angle. As the age of the rider had no influence on the head position, this enhanced vertical vision limit of older riders could be explained by those riders wearing the helmet more downwards towards the face.

*The work carried out within working group WG 1 lead to some remarkable results in summary.*

In general the potential of bicycle helmets appears to be not yet fully exhausted. In particular, a helmet may have additional benefits as device implemented with additional techniques for example as integration of GPS for driver assistance systems. With such development the bicyclist can be integrated in the potential of avoidance strategies of accidents by assistant systems respectively intelligent traffic systems ITS. A helmet can also contribute to the visibility of cyclists and it can certainly also increase the security awareness of the cyclist and thus help to prevent injuries. However, studies have also revealed that helmets can result in a changed behavior of cyclists, which counterbalance the safety effect of the helmet. In this area additional research is required, to transfer the proven benefits of a bicycle helmet into an effective usage in the real world. The analyses of both field studies produced interesting results. The case numbers were sufficient to display tendencies. For more significant analysis or more in-depth analysis, e.g. for comparing countries, more cases would be necessary. Based on these different studies of literature, in-depth-investigations of accidents and field studies on driving behaviors and helmet postures as well as questionnaire requests, problems in helmet usage could be identified and the effectiveness of the helmet protection could be established.

The effectiveness of bicycle helmets in accidents can be established however, there are also studies that question the effectiveness of bicycle helmets in accidents. The effectiveness of bicycle helmets in literature is often discussed in conjunction with mandatory helmet use, for that reason there are a few studies that specifically show the effectiveness of the helmet in relation to injuries sustained and a scientific assessment of the protective potential of helmets in view of certain injury patterns to the head. In particular in Germany, there are few studies on the effectiveness of bicycle helmets, since as yet there is little helmet use, which does not permit statistical comparisons of wearers of helmets with those without a helmet and therefore are mostly exploratory and were conducted using single randomization, for which usually no control groups were available. Only recently have results for the effectiveness of helmets appeared based on accident analyzes for Germany. A study by the insurance company Allianz Versicherung published in 2013 [22], which advocates the use of bicycle helmets noting that seniors constitute 51 % of all pedestrian and cyclists fatalities, one third of all bicycle accidents without involving third parties are falls and the number of unreported cases is very high, which means they are not included in any of the accident statistics. A study by the Universitätsklinik Münster published in 2012 [23] also points that way. Therefore a higher helmet effectiveness can be assumed than given by the statistics. For many European countries no data on helmet use exsist. Helmet use should be integrated in the official data collection by the police in all European countries.

The potential of bicycle helmets appears to be not yet fully exhausted. In particular, a helmet may have additional benefits and give opportunity for an implementation of driver assistance systems. A helmet can also contribute to the visibility of cyclists and it can certainly also increase the security awareness of the cyclist and thus help to prevent injuries. However, studies have also revealed that helmets can result in a changed behavior of cyclists, which counterbalance the safety effect of the helmet. In this area additional research is required, to transfer the proven benefits of a bicycle helmet into an effective usage in the real world.

Helmets have to be optimized by modification of the outer design. It could be pointed out in this study that the impact conditions are not fully covered by the CEN Standard EN 1078. Especially the lateral side is a major impact area, the helmet design have to covered this by extend the lateral proection zone.

Some of the most common health problems and annoyances associated with cycling can be attributed to poor bicycle fit and wrong cycling posture [31, 32]. These problems are usually observed at three areas of the human body, namely the neck, the lower back and the lower limbs and most often the knee [33].

# Recommendations from the study of WG 1

# increase the helmet use in all countries in Europe (helmet is effective against head injuries)
# reporting about helmet use from all countries in Europe (need more information about cycling and helmet use, monditoring of data from hospitals, government and infrastructure, coding of MAIS3+)
# integration of data on injuries into police reports for statistical issues
# optimization of helmet design on the lateral part of the helmet
# modification of the helmet standard within CEN 1078 for protection zone and impact conditions conformity to real accidents
# finding improvements for helmet design and helmet wearing for different kind of bicycles (citybikes, racing-bikes, mountain-bikes, e-bikes)
# Improvements for best helmet position on the head for high safety

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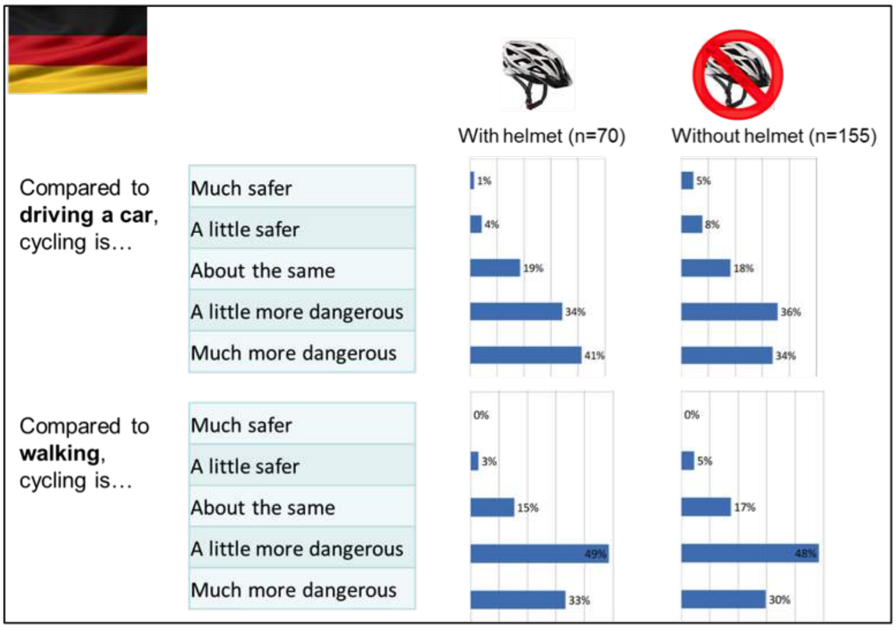
# APPENDIX

# ANALYSIS OF QUESTIONNAIRE

## A.1 Safety sensation

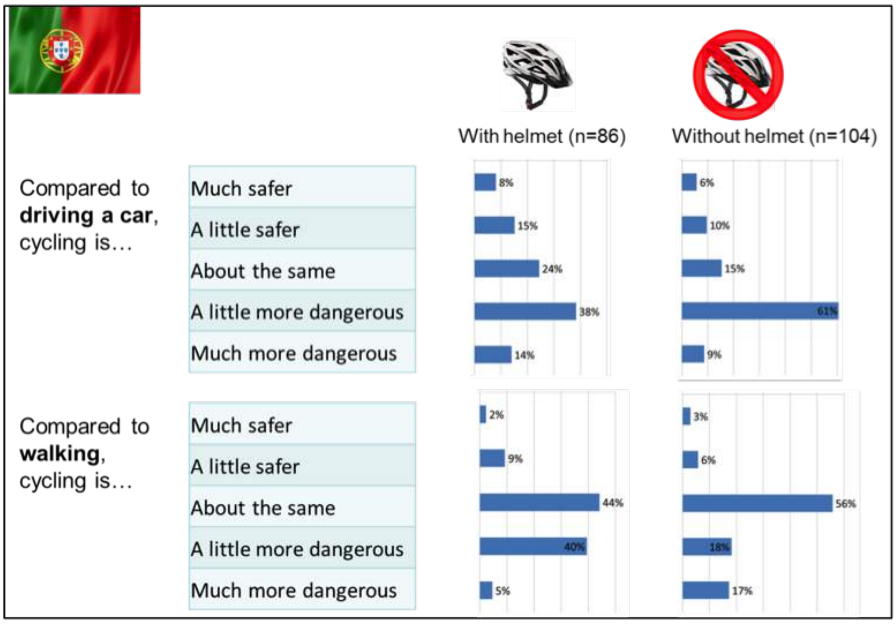



**A.1.1 Safety sensation of cyclists in Germany compared to other types of traffic participation, analysed separately for cyclists wearing a helmet and not wearing a helmet.**


**A.1.2 Safety sensation of cyclists in Finland compared to other types of traffic participation, analysed separately for cyclists wearing a helmet and not wearing a helmet.**

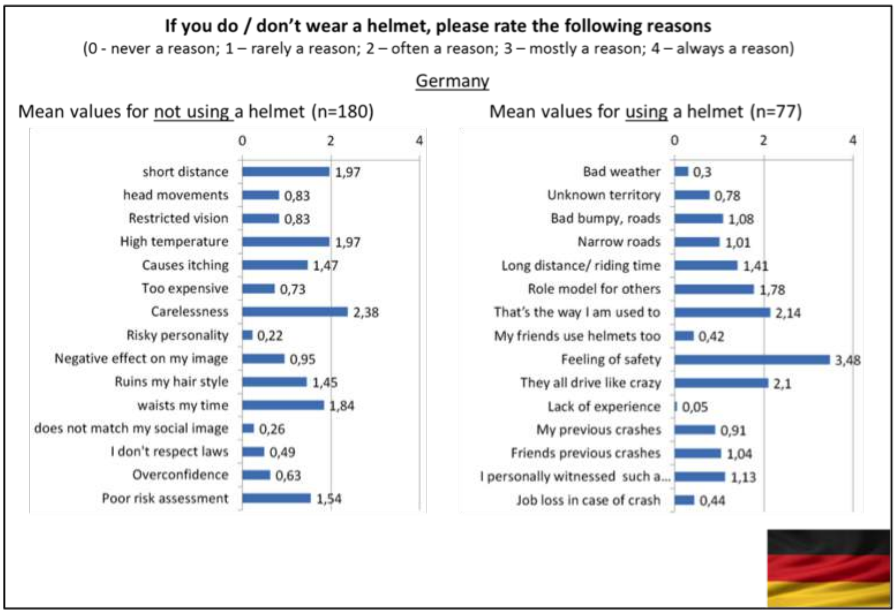

A.1.3 Safety sensation of cyclists in Greece compared to other types of traffic participation, analysed separately for cyclists wearing a helmet and not wearing a helmet.


A.1.4 Safety sensation of cyclists in Italy compared to other types of traffic participation, analysed separately for cyclists wearing a helmet and not wearing a helmet.

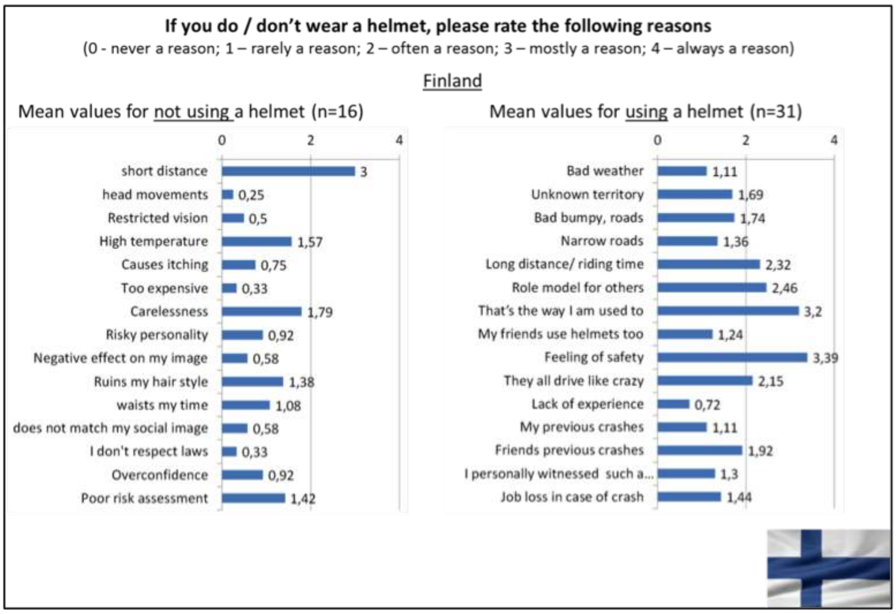



A.1.5 Safety sensation of cyclists in Portugal compared to other types of traffic participation, analysed separately for cyclists wearing a helmet and not wearing a helmet..

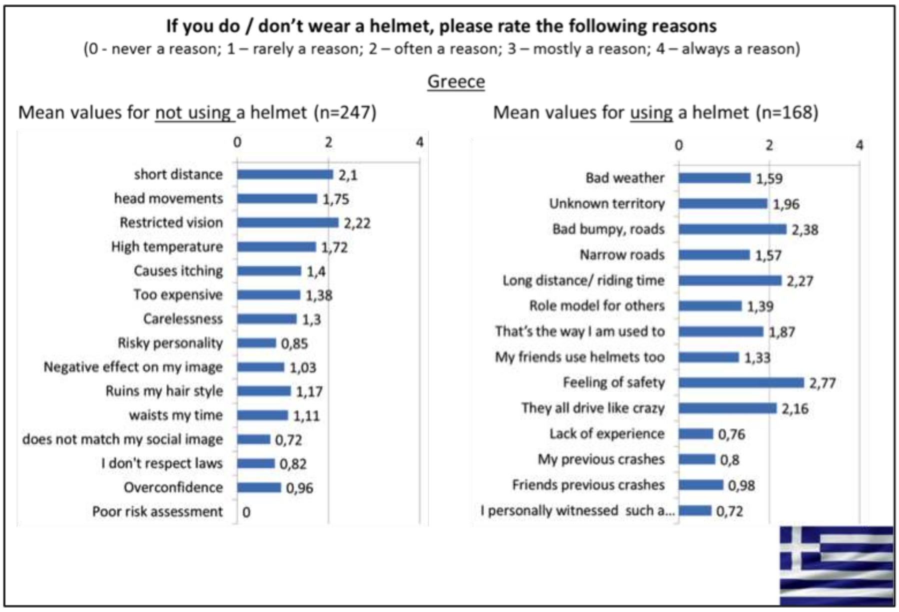
## A.2 REASONS FOR WEARING / NOT WEARING A HELMET.



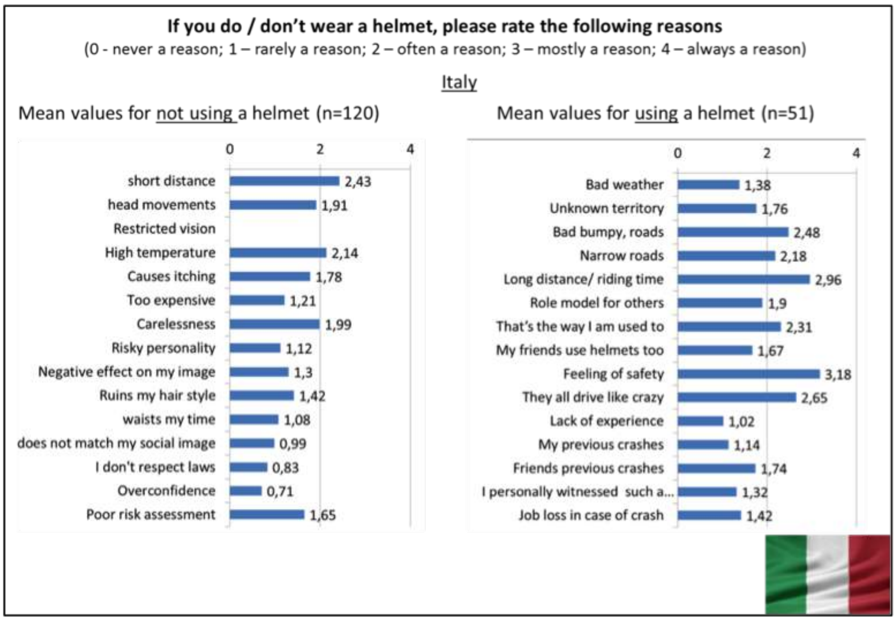

A.2.1 Mean values of the ratings of the reasons for using a helmet and for not using a helmet in Germany.



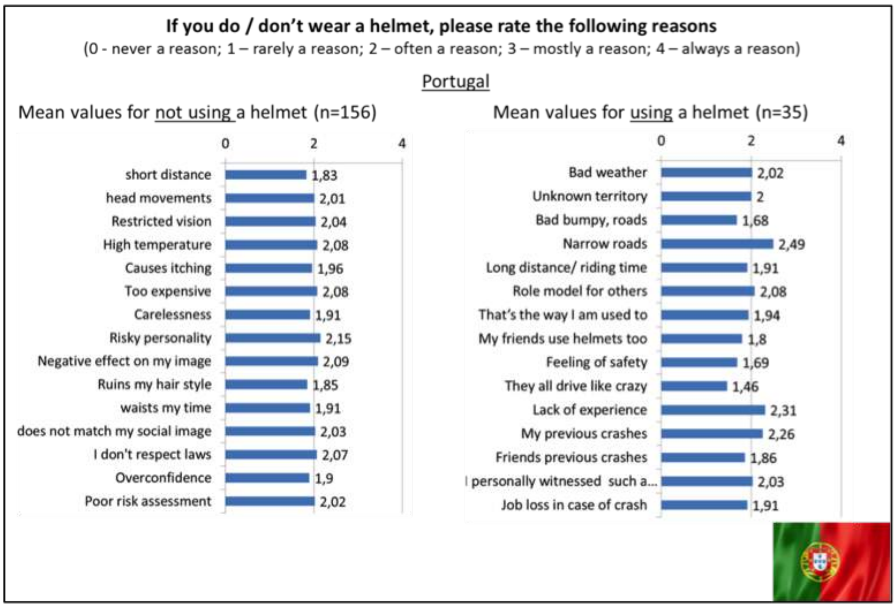

A.2.2 Mean values of the ratings of the reasons for using a helmet and for not using a helmet in Finland.




A.2.3 Mean values of the ratings of the reasons for using a helmet and for not using a helmet in Greece.




A.2.4 Mean values of the ratings of the reasons for using a helmet and for not using a helmet in Italy.




A.2.5 Mean values of the ratings of the reasons for using a helmet and for not using a helmet in Portugal.